AGRICULTURAL GEOLOGY

McCONNELL

NOTICE

It is intended that this book shall be sold to the Public at the advertised price, NET, *and the terms on which it is supplied to the Trade will not allow of discount.*

CROSBY LOCKWOOD AND SON.

AGRICULTURAL GEOLOGY.

London:

Printed by McCorquodale & Co., Limited, Cardington Street, N.W.

THE ELEMENTS

OF

AGRICULTURAL GEOLOGY:

A Scientific Aid to Practical Farming.

BY

PRIMROSE McCONNELL, B.Sc.,

F.G.S., F.H.A.S., M.R.A.S.E. (BY EXAM.),

Author of "Notebook of Agricultural Facts and Figures," "Elements of Farming," etc.

TENANT-FARMER, ONGARPARK HALL, ONGAR, ESSEX.

WITH

Coloured Map and Original Illustrations.

Capio Lumen

LONDON

CROSBY LOCKWOOD AND SON

7, STATIONERS' HALL COURT, LUDGATE HILL

1902

TO MY WIFE

KATHERINE

This Book is dedicated,
as some small recompense for
the patience with which she has endured,
and the encouragement she has given me in,
the writing of the same.

P. McC.

PREFACE.

Some thirty years ago the author of this volume—then working as a lad on his father's farm among the hills of Kyle, in Ayrshire—read Geikie's "Story of a Boulder," and acquired therefrom a taste for geological science, which grew stronger as he grew older. The influence of geological structure, not only in forming the features of the country, but also in modifying the nature of the soils and the farming carried out thereon, struck him very early in his observations, and at least twenty-five years ago he began to systematically study the subject and to collect information thereon. As part of this investigation the consultation of many books was necessary, and in recent years three London libraries have been ransacked—including that of the Geological Society—to find any information bearing on the application of geology to agriculture. In addition, collectors' lists were examined, and in the result a respectable private library of books and pamphlets bearing upon this special line of study has been accumulated.

The greater part of the information, however, for which the author is indebted to books, has been derived from the volumes of the *Journal* of the Royal Agricultural Society of England, extending over 60 years, embedded in which are many Reports bearing directly on the subject. Outside of the English language, the only publication of any value known to the author is Risler's "Géologie Agricole," in French, of which great use has been made, for, strange to say, no German scientist has ever tackled the matter, so far as he can find out.

While many writers have thus been laid under contribution, as is shown by the footnotes, the more important sections of the volume can be claimed as the result of the author's own investigations, carried on for a great number of years. The method he followed was to procure the sheets of the Geological Survey maps for any district to be studied over or even passed through, and to cut them into small squares and paste them on the leaves of notebooks. With these in his pocket, he has worked over hundreds of farms in various parts of the United Kingdom, watched and noted the various kinds of farming passed on railway journeys or on drives, and collected samples of soil for examination where the maps indicated typical surface deposits.

All the information so gathered has been sifted and arranged in the light of his own lifelong practical experience. For the last twenty years he has been farming on the London clay in Essex, and this volume has been prepared in the intervals of leisure in the management of a large holding of mixed husbandry—in the winter evenings, on wet or stormy days, in the summer mornings between sunrise and the beginning of the day's work, and so on; the preparation of the manuscript taking ten years in its accomplishment.

It is now presented to the public who are interested in scientific farming, as an honest endeavour to help on the development of the most ancient and the most important of all human occupations—agriculture.

P. M[c]C.

ONGARPARK HALL,
ONGAR, ESSEX,
June, 1902.

CONTENTS.

AGRICULTURAL GEOLOGY.

CHAPTER I.

IN THE BEGINNING.

When I was a very small boy at school the elementary geography I first grappled with informed me that the earth was an "oblate spheroid," and that this was a proof that it had at one time been a molten mass. When I grew up I had the curiosity to find out what on earth an oblate spheroid is, and I discovered it to be a globe slightly flattened at the poles or spindle-ends, and that this flattening was due to it whirling round in space while in a liquid state.

The ancients believed that we lived on a huge flat cake, and that if anyone went to the edge he would fall over, while now a twentieth century philosopher informs us that the earth is not an oblate spheroid after all, but that it is shaped like a boy's spinning top, dwindling down to a point at the south pole, as we can see proved with our own eyes from the shape of Africa and South America.

Apart from this, scientists tell us that unnumbered ages ago this earth, in common with the whole planetary system, and probably the whole visible universe, existed in the state of incandescent gas or vapour, diffused in irregular patches throughout that mysterious entity we call "Space," and that at least the portion corresponding to our Solar System had a rotary motion from west to east. This theory—known as "*Kant's Nebular Hypothesis*"—most satisfactorily and logically explains the first appearance of this world of ours as read in the light of the phenomena all around us, and is most in conformity with the state of matters at that far-off beginning when "the earth was without form and void." The sixty-odd elementary bodies which compose all matter with which we are cognisant, existed then in the simple uncombined gaseous state, or in such compounds as may remain stable and unchanged at a temperature very much above white heat. In process of time the heat contained in these clouds of nebular matter or incandescent gas radiated off

into the outer regions with the result that eventually the material condensed into the liquid form, and by the ordinary action of the attraction of gravity, *plus* the initial rotary motion, gathered together into the masses forming the suns and planets with which the universe is filled, while the various *nebulæ* known to astronomers are remnants of the gaseous matter which is still in the process of cooling to form new worlds.

In the molten state the earth was surrounded by an atmosphere of various gases, the future water in the form of steam—or its component oxygen and hydrogen gases—composing the greater portion of it. The liquid globe of the earth itself consisted pretty much of molten lava, or of some material—or rather perhaps of a mixture of materials—similar to that of which granite, diorite, lava, basalt, and rocks of a similar nature, are the solidified and perhaps partly altered forms. We do not know what was the character of the rock or rocks which formed the crust of the earth when the surface of the heated mass first cooled.* Some held at one time that granite claimed the highest antiquity, but we now know that granite may be a comparatively recent, as well as a primary igneous (plutonic) rock. Bearing in mind the fact that volcanic rocks—which are recently igneous in contradistinction to the older or "plutonic" forms—take the forms of trachyte, obsidian, phonolite, pumice, volcanic ash, as well as dolerite, basalt, trap, and lavas generally, we are at liberty to assume that the original crust of the earth, formed on the first cooling of the mass, was made up of as diverse materials as the ejectamenta of a modern volcano. It is doubtful if the primitive rock now exists anywhere sufficiently near the surface of the modern world to be accessible,† owing to the denudations, re-deposits, metamorphisms, upheavals, and depressions which have constantly been going on for an unthinkable length of time before the advent of Man; though the "Fundamental Gneiss," or granite-gneiss of Archæan formation, is by some held to be the lowest, or oldest form of rock, or at least the oldest rock in the British Islands.‡ Prestwich says that it is hardly possible at present to draw the line where the original mother rocks end and the derivative strata commence.§

* Rutley: "Study of Rocks," p. 7.

† Stockbridge: "Rocks and Soils," p. 5.

‡ Ramsay: "Physical Geology and Geography of the British Islands," 3rd Edition, p. 44.

§ Prestwich: "Geology," Vol II, p. 19.

Dawson is of opinion that this formation of the Lower Laurentian is the first that ever was formed, as it is the lowest we have access to, and is of exceptional character—aqueo-igneous. It had in the initial stages formed the "slaggy" crust, and shows bedding from cooling in layers under water in the later stages, with molten matter injected into the interstices.*

The time that has elapsed since this first crust was formed has been estimated at various figures by different authorities. Lord Kelvin at one time allowed that it might be as much as 100,000,000 years, he then reduced his estimate to 20,000,000 years. On the other hand, geologists calculated that at the present rate of denudation of one foot all over the land surface in from 4,000 to 5,000 years, the 70,000 feet of sedimentary strata would represent 86,000,000 years, though some—as Wallace, Houghton, and Dawson—reckoned 28,000,000 years as not far off the truth.† These allow, however, that organic life did not appear till about 15 or 16 millions of years ago.

Opinion among scientific men is thus divided as to the time that has elapsed since the globe became habitable. Some geologists require an almost immeasurable number of years to allow for the slow deposition of the strata with their contained fossils, reckoning that changes were as slowly accomplished then as now ; while on the other hand, physicists calculate from the known rate of the cooling of the earth, that it became habitable only about 15½ millions of years ago, and that all the geological changes—or at least the deposition of all the fossiliferous rocks—must have taken place within this time.

As the age of the earth does not particularly concern the object of this book, we may leave it now and let the scientists interested in the matter fight it out among themselves.

Molten material of all kinds contracts on cooling, and if the arrangement of the mass does not allow of contraction, then it will wrinkle up or crack and break. This has happened with the crust of the earth, and the gradual contraction of the mass of the globe from cooling has given rise to wrinkles and creases and fissures, which formed the first hills and hollows—the larger of the latter being filled later on with water to form the first seas. It is, indeed, held by many geological authorities of eminence that these primal folds have remained in existence ever since ; in other words, that

* Dawson : "Salient Points in the Science of the Earth," p. 18.
† Ibid., p. 416.

the larger continents and oceans were then formed, and have remained more or less constant down to the present time; the depressions below sea-level necessary for the vast accumulations of sedimentary strata now forming the dry land above sea-level being only comparatively local and temporary. In this way the Atlantic (North and South), the Pacific, and the Indian Ocean basins are believed to be the "primary grooves" formed on the first cooling and contraction of the crust of the earth, with the corresponding elevations represented by the larger or more elevated continental masses.

In the course of ages the heat continued to be still further radiated outward until the temperature of the outer crust became lower than 212° Fah., when the water, which would previously have existed in immense clouds of steam and vapour, became condensed to form the oceans, seas, and lakes. Once these were formed a new agent came into action, and a new set of circumstances took effect. This was water and its eroding power when in motion.

In the earliest stages of the existence of our globe it is computed that it must have spun round on its axis every three hours, and that the slowing down of the speed to the present diurnal 24 hours was due to the action of the tides—like a huge friction-brake round the earth; while as the moon was then nearer the earth the tides were believed to be as much as 36 times their present magnitude.* The amount of erosion carried on round the shores of the primeval seas by such a mass of swirling and rushing water must have been enormous, and possibly some of the beds of the Laurentian—that great group of sedimentary rocks of five miles in thickness—may owe their existence to the deposition in the greater depths of the oceans of material eroded off the shores by these immense tides.

No one who has not given some attention to the subject, can adequately realize the tremendous wearing or eroding power of ordinary running water when exercised for an immense length of time. A river in time of flood is muddy, and the muddiness is due to the solid particles of earthy or rocky material carried along in suspension, while in addition to this there is always a proportion of solids in a state of solution even when the water is clear; and all this material must have been derived from the surface soil or exposed rock by the water washing over and through the same. The amount of eroded material carried down to the sea has been

* King: "The Soil," p. 17.

calculated for the principal rivers of the world, and, as an illustration, it may be stated that in the case of the Thames, the débris washed away is equal to a lowering of the surface of the whole Thames basin to the extent of one foot in 1,000 years, at the present rate of waste.

When the globe was cooled down sufficiently to allow of the deposit of the water in the seas, the evaporative action of the sun's heat came into force, and the vapour thus formed was in the higher regions of the atmosphere cooled and re-deposited as rain, which collected into streams running down to the sea to be re-evaporated and re-condensed into rain in a continuous cycle ever since. When the earth itself was hotter, and possibly the sun's rays stronger, the evaporation and condensation would be much greater than we now have at this period of the world's history; that is, tropical and excessive rains would be the normal state of the weather, with a corresponding excessive erosion of the land's surface by the floods, together with a tropical growth of plants.

The mass of the earth is always radiating off some of its heat continuously into space; that is, the cooling process is still going on. The internal temperature has no appreciable effect on the surface now, excepting in such phenomena as volcanoes, hot springs, and features of this sort, while the process of radiation has been materially hindered or helped by the arrangement of the strata at a particular spot. Flat strata have retarded the escape of the heat, and vertical strata have helped the same, while likewise allowing of a more easy percolation of the rain. Thus the cooling has gone on unequally in different regions. One instance may be given of that of Astley pit in Cheshire, where the rise in temperature is 1° in every 35 feet of descent, but the observed average of many mines in different parts of the country is 1° in 54 feet.* This, of course, has very little effect on the surface conditions now, though there is no doubt that at one period in the earth's history it must have excercised a vast influence on the animal and vegetable life of sea and land, in much the same way that "bottom heat" acts in a gardener's forcing frame in the modern world.

It is believed that vegetable and even animal life was possible when the "water under the earth" had got cooled down to about 190° Fah., yet estimations made indicate that the temperature of the earth's surface at the close of Archæan time was still about

* Cooley: "Physical Geography," p. 81.

100° Fah.,* the present mean annual surface temperature being 49° Fah.†

All the known land must have been under the water at one time or another, whether a "primal fold" or not, and in most cases for a long time. Tennyson was not a geologist, but he stated facts better than any of the clan when he wrote :—

> "There rolls the deep where grew the tree,
> O earth, what changes hast thou seen !
> There where the long street roars, hath been
> The stillness of the central sea.
>
> The hills are shadows, and they flow
> From form to form, and nothing stands ;
> They melt like mist, the solid lands,
> Like clouds they shape themselves and go."

When any given area of land first appeared above the waters it must have been nothing more or less than a hump or boss of igneous rock, similar in appearance to a volcanic island, but varying in size from a small reef to a huge continent. The rain falling on such immediately collected into streams and began to run seawards, gradually wearing out water-courses and valleys as the time went on. The greater part of this eroded material was carried out to sea and deposited in layers, forming the various strata which compose the whole series of stratified rocks, but a small portion would always be deposited on the level parts of a river course, or at the mouth of the same, forming the basis of the level alluvial or estuarine soils of the world.

By the time this stage was reached other forces had come into action : such as the power of oxygen to chemically combine with every substance oxidizable at ordinary temperatures, the solvent power on limestone of water containing carbonic acid gas, and the effect of rising and falling temperature on all exposed material. Iron in particular of all the ingredients composing the rock-forming minerals has an affinity for oxygen, forming the protoxide and peroxide of iron (rust) and thus breaking up the cementing power of the original iron in the rock and allowing the other mineral matter to collapse or form friable débris which in turn helped to form the mineral basis of soils : while the same happened to any mineral or rock containing carbonate of lime when acted on by water with $C\,O_2$ in solution.

Again, when the temperature became cool enough to allow of

* Stockbridge : "Rocks and Soils," p. 7.

† Prestwich : "Geology," Vol. II., p. 537.

the action of frost, the freezing of the water in the seams and pores of exposed surfaces caused the breaking off of scales and even slabs and chunks, this going to still further augment the amount of débris.

On a level surface, or where there was little washing power of water, this débris accumulated and thus the bulk of the first soils was formed, and the formation has been going on in the same way to this day.

The above is a short summary of the process of formation of the solid crust of the earth with the interdependent arrangement of sea and land, cloud and sky. The origin and formation of soils, with all that is involved therein, rightly began only after the globe had cooled down sufficiently to allow of the existence of water, clouds, rain, frost, and animal and vegetable life of low grade; when, in fact, the formation of the geological strata began. Indeed, the formation of a soil and a bed of sediment have been largely due to the action of the same agents, and much that will appear hereinafter will apply equally to both phenomena.

There must have been an endless succession of soils formed and destroyed in the course of geological time, for every land surface which supported plants and animals must have had some sort of soil thereon, while any geological change must have meant the destruction of the same. But few records are left of these old land surfaces, though there must have been such from very remote geological time. Some of these ancient soils have been preserved, however; fossilized, as it were, in some cases.

A good example is found in most coalpits. Underneath the beds of coal there is usually found a layer of a particular kind of clay—used now, in the arts, under the name of "fire-clay," because bricks and other things made out of it stand the continuous action of fire much better than those made from ordinary clay. From the fact that it is often full of the roots of coal plants (*Stigmaria*) it is held that this is the soil on which the coal plants grew when it was existing as mud at the bottom of a marsh or lagoon. A peculiarity of this ancient soil is that it is deficient in potash, soda, and other elements of fertility which are conspicuous and necessary ingredients in the greater part of the soils of the present time,* but the absence of which prevents fusion or

* Shaler: "Origin and Nature of Soils." *United States Geological Survey Annual Report*, 1891, p. 322.

vitrification when exposed to intense heat, as would be the case with ordinary soils. Every seam of coal must have had its corresponding soil: in the South Wales coalfield there are 100 seams with the corresponding soils on which the trees and plants grew,* while in Nova Scotia Dawson noted 68 root-bearing soils in a thickness of 1,400 ft. of coal strata.†

In the railway cuttings through the chalk near Tring there is a still better example of an ancient soil. The older chalk rock has formed dry land at one time, sufficiently long to allow of the denudation of the same, and the accumulation of a soil thereon of brown loam about six inches thick—representing the insoluble residue of probably 10 to 20 ft. of weathered chalk carried off in solution. This old surface has been submerged again so gently as not to disturb the soil on the same, and the deposition of chalk has recommenced and covered it up to the depth of many feet. Finally, the elevation of the whole to form part of the Chiltern Hills has allowed of the second denudation and formation of the soil of the present day—now farmed and cultivated, and forming a retreat for weary members of Parliament.

That the old soil, dating from the middle of the Upper Cretaceous period, is still a soil proper—though "fossilized" for ages—is shown by the fact that whitethorn and other plants have taken root in it, and grow where its section is exposed on the sides of the railway cutting.

Another example yet again: in the opinion of some geologists the laterite or bed of "red bole" which occurs in connection with the deposits of basalt in Antrim and the north of Ireland generally, is also the remains of an ancient soil. The top of the lower basaltic beds was weathered to form this soil material, possibly mingled with volcanic ejectamenta, on which in later ages another layer of molten basaltic lava was poured out, thus embedding it and burning and metamorphosing it into material like red brick clinkers; the associated deposits of lignite and beauxite representing the fossilized vegetable matter.‡

As a matter of fact many such old soils must be in existence if we knew where to look for them and recognised them. We can see that their preservation must have been due to an accident, however,

* Woodward: "Old Land Surfaces," p. 4. *Geological Magazine*, Nov., 1871.
† Ibid., p. 8.
‡ Green: "Physical Geology," p. 146.

when we realize that the depression of a land surface below sea or lake level must have been accompanied in the vast majority of cases with a destruction—or, at least, jumbling up—of all loose top accumulations from the action of waves or currents. When we come to think of it, however, there must have been soils corresponding to all the strata we find forming the sedimentary accumulations of the crust of the earth, or at any rate to the most of them. The greater proportion of the strata represent the débris or washings from off land surfaces carried down by rivers and floods, while this débris in its origin is exactly the same material as that which goes to form soils when left to accumulate on the dry land, and as the whole of it was not carried out seawards to form beds, some remained behind to form a soil-covering. The existence of fossil land plants, and also of animals, is proof of the existence of a soil yielding food for the same, and while every bed may not have had a special land surface and soil corresponding to it—as one set of land conditions may have existed right through the time several different strata were being deposited,—it is certain that groups of related or similar beds must have had the same or similar land surfaces, with soils which in many cases left no trace behind when the conditions were altered.

Some of these old land surfaces, however, with their soils containing roots are reckoned "formations" in the ordinary geological sense, and classed in lists as such. In addition to the two examples just given, we may instance the brashy Purbeck "Dirt Beds" of the Upper Oolite, identical in composition with the present surface soil,* and containing the silicified trunks of cycads and stools of conifers preserved *in situ*;† the Oligocene "Leaf Beds" of Antrim, Mull, and Skye; and the "Forest Beds" and submerged forests of the Pliocene; while a closer examination of formations from this point of view would result in discovering the traces of others scattered up and down through the long series of deposits. An "uncomformity" is the most likely place to find such, because it represents a denuded surface on which a soil might have existed before re-depression gave an opportunity for depositing other rocks on the same, as exemplified in the case of the chalk near Tring above mentioned. Every deposit of carbonaceous material, however,—such as the Kimmeridge series,

* Green: "Physical Geology," p. 144.
† Woodward: "Old Land Surfaces," p. 3. *Geological Magazine*, Nov. 1871.

the Triassic coal of Virginia, the lignite deposits, and so on—as also all mammalian and other fossil remains of air-breathing animals, are indications of old land surfaces with soils thereon.

The discovery and study of these primeval soils would be certain to lead to interesting results. Fossil plants are minutely studied by professional geologists—the study of the soils on which those plants grew ought to be just as important.

The age and position of a given series of rocks are partly known from the associated fossil plants, and as we know that in the existing conditions of things certain plants often have a predilection for certain soils, and certain soils are formed from the débris of certain specific rocks, we may infer that there were the like conditions of things in the far past, and that if fossil plants (and even animals) could be collated to the soils on which they grew, and these soils to their parent rocks, there would be many interesting points in Historical Geology brought out.

The Great Ice Age.—Yet further again, there has been one powerful agent which has sculptured out and tremendously modified the surface contour and moulded the face of the country in many places into its present general appearance. This has been the action of ice with its concomitants—the expansive force of freezing water, together with the effect of great floods of water from the after melting of that ice. There has been, to put it shortly, a covering of glaciers more or less all over the northern parts of these Islands, as also of the Continent and North America, existing during what has been called the "Great Ice Age."

Whatever theories are held by various authorities respecting the existence and duration of a "Great Ice Age" or "Glacial Epoch," there is no doubt about the fact that there are large accumulations of surface "Drift" of various kinds over the greater proportion of the northern parts of the United Kingdom which, to some extent, "mask" the underlying "Solid" formations. So much is this so that many writers have gone so far as to say that any attempt to trace a soil to its original rock is futile,* and that where this series of beds occur the rock of the district has no influence on the surface soil whatever. This may, perhaps, be true in some cases, as on a great continent like North America, where, according to Merrill,† the whole of the original soil formation of New England

* Merrill: "Rocks, Rock-Weathering, and Soils," p. 351, &c.

† Ibid., pp. 291 and 351.

has been eroded off by glaciers and "dumped into the Atlantic," while a new lot—"a mongrel horde"—has been brought from the far north and laid down; but within the narrow area of the British Islands the transport of such materials has been on a very much smaller scale, and it is quite possible in a large majority of cases to assign local deposits of this nature to their sources. Even on the continent of North America it is held by some that the limit of the distance of transportation of the "Drift" is 100 miles, while the average is 50 miles.*

Further, it so happens that the special case of New England cited by Merrill to prove his contention that there is seldom any connection between the surface accumulations and the deep-seated rocks was investigated 50 years ago by the late Professor J. F. W. Johnston, who came to the opposite conclusion, and who, moreover, wrote a lengthy treatise showing the intimate connection that *does* exist in the New England States between rock and soil. As this report is buried in one of the old volumes of the *R. A. S. E. Journal*† it is just possible that Professor Merrill did not know that the bottom was knocked out of his statement nearly half a century before it was made. The present writer has had an opportunity of examining the soil in Massachusetts and Vermont—has, indeed, secured samples for his collection of soils,—and is satisfied that Johnston is right: if the original local material has all been "dumped into the Atlantic" then the new stuff brought down and deposited yields soil exactly the same as that *in situ* would have done—as the subjacent rock would do. As Merrill's statement is so positive, and he is the spokesman of many who hold the like opinions on this point, it is necessary that I should adduce some specific cases to prove the contrary in his own region, so here they are:—Prince Edward Island is composed of red Triassic sandstone; the soil is a red sandy soil,‡ when on Merrill's theory it ought to be the slaty-coloured stiff soil derived from the Laurentian rocks. The famous Annapolis Valley and adjoining district in Nova Scotia ("the home of Evangeline") is of Triassic formation with a corresponding red sandy marl soil, though it is completely hemmed in by Silurian and Cambrian rocks.§ The Silurian rocks of

---

* **Stockbridge**: "Rocks and Soils," pp. 46 and 49.

† **Johnston**: "The Relations of Geology to Agriculture in North Eastern America." *R. A. S. E. Journal*, 1852, p. 1, and 1853, p. 1.

‡ **Fream**: "Canadian Agriculture." *R. A. S. E. Journal*, 1885, p. 425.

§ Ibid., 1885, p. 431.

western New York "plainly exhibit to the eye of the observer the chemical characters of each, the kind of soil which in crumbling it naturally produces, and the special effect it has on the agricultural capability of the surface that rests upon it"*—and so on *ad infin.* with the Medina sandstone, Clinton group, Niagara limestone, and all the rest of the rocks met with in that region. But there is more evidence to hand on the soils of North Eastern America, as the following quotations from the *Report on the Surface Geology of North Eastern New Brunswick*, by Chalmers, indicates.† "No traces of glaciation were observed, apparently all the excavating and sculpturing which fashioned these ancient hills having been effected by subærial disintegration." (p. 7.)

"Evidently the ice of the glacial period, in its eastward passage over the surface of the Middle Carboniferous area here, thinned out and was not of sufficient thickness or weight to displace or remove the whole of the pre-existing decayed rock material." (p. 11.)

"In all cases the till, where observed, seems to be largely derived from pre-existing rotted rock belonging chiefly to the underlying formations in each particular locality, but somewhat changed in mechanical consistency and appearance by glacial action." (p. 12.)

"Even when the surface is strewn with boulders foreign to the particular locality, the great bulk of the deposits belongs to the underlying rocks." (p. 28.)

Another quotation or two in the same line may be given from another authority—Crosby's *Composition of the Till or Boulder Clay of the Boston Basin*:—"It follows that substantially as much chemical detritus as now exists in the till must be referred to pre-glacial times, and regarded as representing the soil (chiefly sedentary) which covered the glaciated regions before the advent of the ice." (p. 131.)

"This means that possibly as much as one-fourth and quite certainly not more than one-third of the detritus composing the till of the Boston Basin was in existence before the ice age." (p. 132.)

If these things are so on a huge continent like America, where the glaciers were of infinitely greater size and travelled further than on a few small partially submerged islands like the British

---

* Johnston: *R. A. S. E. Journal*, 1852, p. 7.

† *Geological and Natural History Survey of Canada*, 1888.

group, then it must be equally so, if not more so, the case in these Islands of ours.

Another point which is quite lost sight of by those who oppose the idea of collating soils to formations, is the fact that glacial deposits are themselves a formation or group of formations, and as such ought to be studied in the same way as any other formation. Merrill has invented the name "Regolith" for the loose covering of materials which covers the hard or "solid" rocks—a name which is quite appropriate in some cases but not in others. It is not applicable, for instance, in the case of the London Clay and other clay formations, where the subsoil insensibly passes into the solid "rock" of the formation—where, indeed, there are no surface accumulations, but merely the top of the original formation weathered down *in situ* and mixed with a small proportion of organic matter.

Where there is in these Islands, however, a covering of loose transported material, it partakes more or less of the subjacent formation, or from one near at hand, as will be shown in detail below.

In any case, and apart from this, the fact must not be lost sight of, as will be gone into later on, that the geological structure influences many more things besides the composition and texture of the soil; matters that are of as much importance as the soil itself. Mountain, river, lake, and plain are all physical characteristics affecting farms, and due to the geological structure below as well as at the surface, and where the soil itself on a particular field or farm is of obscure derivation and does not fall into line with the usual rule, the other geological influences and circumstances remain the same.

There have probably been a series of glacial epochs occuring at intervals throughout geological time, while the last is considered to have occurred in two periods with a mild climate between—at least in the opinion of the Scottish geologists; probably because the phenomena are best developed in Scotland. Elsewhere there is no proof of this, while it is noteworthy that Agazzis the naturalist never saw "Boulder Clay" excepting in Scotland.* For the purposes of this book the deposits will be treated as one series, for from a farming point of view it matters not whether a particular farm or field lies on the wreckage of the first or second glacial period, and

* Horre: "Boulder Clay of Europe." *Trans., Roy. Soc., Edin.*; XXV., ii., p. 659 (1869).

American geologists incline to believe there was only one period.* Opinion is divided as to the cause of this phenomenon, and we need not waste time in vain speculations on the same, but it appears that the "Ice Age" finally came to a close somewhere about 8,000 years ago.† This means that for the most of the northern part of the northern hemisphere the soils began to be formed, the vegetation and animal life to spread northwards from the south, and the smaller natural features of the country—such as brooks, rivers, meadows, straths, peat-mosses, and the vegetable mould—to come into existence.

This glacial covering extended—with some exceptional spots—as far south as the middle of England, over the most of Wales, over all Ireland (excepting part of the south-western district), and over the whole of Scotland: while the southern edge has been traced across the middle of Germany. On the North American Continent it reached down to New York and Ohio, and further south in a spur or separate "field" on the Rocky Mountains, leaving a string of morainic deposits more than 3,000 miles in length across the Continent. Wherever it reached and covered the rougher features of the country were rubbed off, leaving rounded hills and bosses of rock; hollows and valleys were filled up in places with boulders, gravel, sand, or clay, or mixtures of these; valleys were scooped out and widened in other parts; lakes were eroded in valley bottoms or formed by a damming up with detritus; river courses were changed, and in short the whole natural features of the country were considerably modified; while the melting of this load of ice left the country bare, barren, and bleak, the floods of water resulting therefrom washing out, resorting, mixing, and re-depositing the detritus in all sorts of ways.

Possibly the land extended much further south in the British area than it does now, and was even joined to the Continent, but it is still a moot point whether glacial Britain was a cluster of low ice-clad islands, or a highly elevated glaciated region surrounded and united to continental Europe by a great plain inhabited by an abundant flora and fauna;* one authority maintaining that Scotland stood 1,000 feet higher than it does now.†

* Dana: "Geology," p. 561. McGee: "Geology and Agriculture," p. 10. *Trans., Iowa State Hort. Soc.*, 1884.

† Dawson: "Salient Points in the Science of the Earth," p. 476.

‡ Bulman: "Glacial Geology," p. 19. *Geological Magazine*, Sept., 1891.

§ Dana: "Geology," p. 542.

In England the whole district of East Anglia is largely overlaid by the "great chalky boulder clay" as far south as the edge of the Thames Valley. The majority of geologists hold that there was no ice over this region, but that icebergs from the Lincolnshire Wolds or from further north dropped their débris over it when depressed below sea-level, or covered by the waters of an "extra-morainic" lake. The present writer agrees with this view—a view supported by Lewis,* Wood and Bennet,† and Prestwich.‡ Geikie (J.) holds, of course, the opposite view.§

For our own islands, therefore, we may take it that the retreat of the glaciers left the country (where they existed) without soil—bare rock in some parts, clay in others, sand or gravel in others again, and so on, according to the district and the nature of the subjacent solid rocks; and we must later on see how a soil was formed out of these, and how the various soils are different one from another according to the nature of these subjacent rocks.

It is just as well to understand that the melting of the glaciers and the disappearance of the "Ice Age" was a very gradual affair, spreading over a very great period of time, as measured by human history. We read in geological text-books about "débâcles" (immense volumes of water set free on the melting of the ice) and so on, thus giving us the idea—unintentionally, no doubt—that the "Ice Age" suddenly ceased to be, and the ice commenced to melt at an extraordinary rate, setting free whole seas of water in a single summer or so. As a matter of inference, after the cold seasons reached a climax, the return of more genial summers came very gradually, and the annual seasonal melting of the ice thus became greater than the advance, so that the amount of water to run off down the valleys was probably little greater than the drainage from the Alaskan, the Alpine, or some of the other great glaciers of the present day. There is no doubt that there must have been a lot of water on the land—if the land were not actually submerged below sea-level; but that derived from the melting of the ice was set free in comparatively small quantities and over a great number of seasons. Indeed, one man has written two

* Lewis: "Glacial Geology of Great Britain and Ireland," pp. 26, 60.

† Bennet: "Glacial Question and Drifts of East Anglia," p. 257. *Proceedings: Norwich Geological Society*, 1884.

‡ Prestwich: "Geology," Vol. II., p. 445.

§ Geikie (J.): "Great Ice Age," p. 354.

huge volumes to prove that there never were any glaciers at all, and that the whole of the "glacial phenomena" is attributable to the action of water while the land was wholly or partially submerged.* All the same, there must have been ice—and a lot of it—at one time to account for the unmistakable evidences of glaciation in northern districts; such evidences as the striæ down the valleys in the Highlands and Southern Uplands of Scotland, the loose accumulations of gravel, sand, and clay in various parts (and containing striated boulders), the rounding-off of hills and knolls looking down a valley, and so on. It was not anything of the nature of one continuous "sheet," but simply an agglomeration of glaciers streaming down the valleys from the various higher centres of the country, overriding smaller eminences, and in some places joining to form larger glaciers working seawards, with occasional bare patches of country between.

The accompanying map will best illustrate the occurrence of glaciers in their greatest extent in the British Islands, founded on the investigations of Professor Carvill Lewis.† It will be seen from this that there was nothing of the nature of a "Polar Ice-cap"—one huge body of ice creeping down from the North Pole—but simply that, following on the existence of cold, combined with a large supply of atmospheric moisture, each mountain or range of high land had its own local glaciers working down the valleys seawards. Thus the highlands of Scotland sent its ice outwards all round—on the west going clean over the Lewis and Western Hebrides, and on the south meeting that coming from the "Southern Uplands" and the united streams dividing east and west down the Firths of Forth and Clyde. These "Southern Uplands" again sent their ice-sheets south to mingle with those of the Pennine Chain, and reached the coasts of Ireland, North Wales, Cheshire, and Lancashire, and went right over the Isle of Man. Wales had three distinct sets of glaciers flowing down all round from Snowdon, Plynlimmon, and Brecknock Beacon, and depositing a string of moraines or morainic débris approximately all round its own borders. Ireland sent its ice east and west from the rugged mountains on the Atlantic boundary, while the Wicklow Mountains, the Commeragh Mountains with Knockmeledown Mountains, and the Killarney Mountains had each separate ice fields of their

* Howorth: "The Glacial Nightmare."

† Carvill Lewis: "The Glacial Geology of Great Britain and Ireland."

own. Not only, however, were the glaciers thus comparatively local at the greatest period of glaciation, but they became still more local as the cold decreased and the ice gradually melted away or "receded." The amelioration of the climate or the lowering of the land—or both together—caused the ice of the lowlands or at sea-level to disappear, while only smaller glaciers remained in the higher valleys, and the latest or surface deposits of the débris are thus exceedingly local. It is this fact which helps us to unravel the question of the origin and composition of the surface deposits in glaciated districts to an astonishing degree. If the ice-cap had been one huge sheet coming from the north then the débris would have been hopelessly mixed, but as almost each mountain was a source of a set of glaciers of its own, flowing down its own adjacent valleys, the deposits of the same are thus of local origin, moved only a few miles from the parent rock—perhaps only a few yards. This is the explanation, or at least one explanation, of the relationship of the surface accumulations to the subjacent rock. The glacial deposits are themselves "formations," and the agricultural characteristics of Kames, Moraines, Boulder Clay, and all the rest of them will be discussed in due course, while the "solid" geology of a given district or a farm must be studied subject to the existence of these surface or "drift" accumulations; but given a certain "drift" formation it is possible within limits to collate it to its origin and thus gain valuable information.

There are considered to be, at least in Scotland, an Upper and a Lower Boulder Clay, with intervening and succeeding sands and gravels. These are taken to be the produce of two successive periods of glaciation with an intervening period of recession. The lower is much the harder and more indurated and completely unstratified, while the upper is looser and with some appearance of stratification in places. As pointed out above, however, this division is not found elsewhere, and for our purpose the series will be treated as one group.

Glaciers account for the rounding off of the lower hills, the striation of the rocks, the widening of the valleys, the erratic boulders about the country, but they certainly do not account altogether for the formation of the Boulder Clay, the "Drifts" of sand and gravel, and various other analogous surface accumulations. The "*moraine profonde*" is a myth, or at least has a doubtful existence, and by no conceivable melting of ice could water enough be produced to sort out and bed these materials as we now find them. It is more

than probable that it was done on the submerged bottoms of the valleys—the "fiords"—and low-lying districts, in which melting glaciers, floating icebergs, and the wash of the sea were all combined, as under such circumstances the débris brought down by the ice would be mixed with a sufficient amount of moving water to arrange and deposit it in the various beds. At the same time it must be acknowledged that no theory or hypothesis yet invented explains or accounts for *all* the points in connection with the deposition of the Boulder Clay, though that of a glacier or ice sheet coming down a submerged valley or lowland, as shown in the accompanying diagram, is the best explanation yet given. Where the ice floats

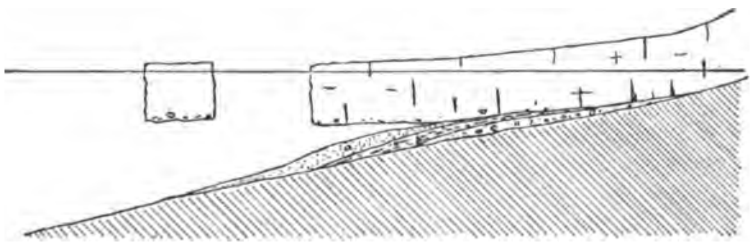


FIG. 1.

GLACIER ENTERING THE SEA, DEPOSITING CLAY, SAND, GRAVEL, AND BOULDERS, AND DISCHARGING ICEBERGS.

a—Sands and Gravels. *b*—Stratified Boulder Clay. *c*—Unstratified Boulder Clay.

out on the water there is an angle formed with the bottom of the sea, and in this the detritus accumulates—Boulder Clay proper. This is the only way it could have accumulated, for ice from 2,000 to 4,000 feet thick on the land could never have allowed of the accumulation of a *moraine profonde* of 90 to 100 feet deep of "till," or more than 100 feet deep,* but it could have been formed as above. As the angle between the bottom and the ice widened out the sea water occupied a wider space, and the currents of the same had room to work, so that the top part of the detritus could be washed and mixed up into a partial stratification, while further out in deeper water the clay was carried off and only sands, gravel, and boulders left. As the icebergs broke off they carried a further burden of detritus to drop as they melted, and thus give rise to the occurrence of erratic boulders.

* Geikie (J.): "Geology," p. 372.

If it be urged that there is not room or extent for the development of a great sheet of boulder clay and its allied deposits at the sea-end of a glacier, then it must be pointed out that even the glaciers and icebergs of the present day are large enough for this purpose. The ice over the Highlands is computed to have been from 2,000 to 4,000 feet thick, but Antarctic icebergs have been met with over a mile in thickness,* proving that the parent glacier must have been at least the same; while as to extent, the Humbolt Glacier in Greenland is 60 miles wide—large enough to lay down a deposit extensive enough to cover at least the half, if not the whole, of the Lowlands of Scotland. "The ice (of Greenland) is pushed for scores or hundreds of miles down into the sea until it gets out of its depth, and eventually floats off as icebergs."†

Of course the smaller physical features are no doubt largely due to the water streaming away from melting ice on land—such as kames, eskers, terminal moraines, beds of sand and gravel, and so on—but the great Boulder Clay and "Drift" required the more important agents in their manufacture such as those just described. The Boulder Clay in Great Britain and other northern regions is so important a formation, however, and has modified the country and farming so much where it occurs, that some more attention must be devoted to it later on.

The Boulder Clay has not only influenced the soil-formation and the scenery of the regions where it is found, but also the races of men, according to Shaler: "The soils of these regions have been the nurseries of our race. The Aryan folk, according to the opinion of those who have most attentively studied their unwritten history, appear to have attained their character in the glaciated districts in and about the peninsula of Norway and Sweden. Their name signifies *ploughman*, and they were probably the first people who used this instrument on the stubborn boulder-set fields of that part of Europe; perhaps, indeed, the first to nurture the earth with the aid of the plough. Their descendants in Scotland, northern and central England, and by far the larger part of North America which lies north of the Potomac, the Ohio, and the Missouri, have dwelt on débris of glacial origin. The soils of these once ice-ridden fields are rarely of great natural fertility, but with labour and care they

* Geikie (J.): "Outlines of Geology," p. 65.

† Campbell: "Glaciation of Ireland." *Quart. Jour. Geol. Soc.*, May, 1873, p. 225.

generally afford a tolerably certain return to the husbandman, and endure very well the tax he puts upon them."*

It is rather strange to find that a generation or two ago the study of agricultural geology should have been an important branch of science, but that in our time it should have been dropped almost entirely out of sight. William Smith, "the father of English geology," was a land surveyor and valuator, and devoted himself to the evolution of the science chiefly as a means of guiding him to understand the values, characteristics, and systems of management of estates, farms, and fields, and he loved to collate the farming to the formations.† De la Beche, the first Director of the Geological Survey, made his name and gained his experience in working out the agricultural geology of Devon and Cornwall, and indeed it was largely owing to this work of his that the Geological Survey was originated. In 1837 John Morton, agent of Lord Ducie, published a volume on "The Nature and Property of Soils, and their Connection with the Geological Formations on which they rest," which reached a fourth edition in six years. In 1842 Professor Johnston issued his famous book on the "Elements of Agricultural Chemistry and Geology"; this is now in its 17th edition, and the few chapters in it on geological matters are literally all that has been placed before students or other enquirers on the subject for about half a century. This book, indeed, is partly the cause of the neglect of the study of the subject for nearly two generations, an assertion which will be understood when I state that in the latest edition only some three or four chapters out of a total of 47 are devoted to this subject. The effect has been to exaggerate the importance of chemistry and minimise that of geology, and thus for nearly sixty years agricultural science has meant agricultural chemistry. The recent development of agricultural education, however, has brought out the importance of other subjects, such as engineering, botany, entomology, bacteriology, as well as geology; and at some of the colleges now there are Professors of Agricultural Geology, but hitherto this latter science has been in a dormant state for a very long period.

As illustrating the high esteem in which the subject was held

* Shaler: "Origin and Nature of Soils." *United States Geological Survey Annual Report*, 1891, p. 239.

† Trimmer: "Geology of Norfolk as applied to the Soils." *R. A. S. E. Journal*," 1846, p. 446.

in those early years, it is noteworthy that the very first article in the very first number of the *Journal* of the R. A. S. E. is one by Pusey on the position of agricultural science, in which a passage occurs eulogising and illustrating the value of geology to farmers; and in the same volume is a special article on the subject by Sir John Johnston, Hackness, Scarboro', while in Vol. III. De la Beche gives his above-mentioned elaborate treatise on the agricultural geology of Cornwall, Devon, and West Somerset. So important, indeed, was the subject then considered, that scarcely a volume was issued without some article on it or reference to it, while nearly every one of the reports on the farming of the individual counties which appeared from year to year contained information on the influence of the different formations on the farming carried out on their out-crops. The author has ransacked all the 120-odd volumes issued since the first one in 1840, and much of the special information given in the following pages has been dug out of this quarry, as the footnotes testify.

The apathy of our government authorities to everything connected with agriculture in this country is in no way better illustrated than in the case of the Geological Survey. As already mentioned, it was because of its agricultural value that early investigators, like William Smith in England, first gave attention to the study of rocks; it was largely owing to the enquiry into the agricultural geology of the West of England by De la Beche that the Geological Survey as a government department was established; and the "charter" of the Geological Survey specially authorises its officers to examine, collate, classify, and map soils and surface formations so as to be of value to those interested in the land; yet, in spite of all this, the agricultural side of the work was for a long time systematically ignored and evaded as far as possible. When the Director of the Science and Art Museum, Dublin, officially visited the museums of the United States and Canada he did not think it worth his while to visit the agricultural part.*

Within the last 30 years, however, a start was made with the issue of the "Drift Maps," showing the surface formations, and the sheets for some of the eastern and northern parts of England have been issued. Quite recently, again, evidence has been forthcoming that the Board of Agriculture are preparing soil maps,† so, as

* Blue Book: "Report—Science and Art Department," 1885, p. 338.
† Blue Book: "Report—Science and Art Department," 1897, p. 321.

everything comes to those who wait, we shall no doubt have a full, true, and particular account of these matters in the fulness of time.

As usual, other countries lead the way in all things pertaining to the development of agricultural science, and never hesitate to vote public money to pay the expense of investigations in this line. In the United States, for instance, not only do the Geological Survey officers give special prominence to the agricultural features of their work, and issue "memoirs" like Shaler's "Origin and Nature of Soils"—a large and well illustrated volume of itself—but the Department of Agriculture has commenced the mapping of the soils, and the issue of reports and coloured charts concerning the same.* Personally, I think they are working on a wrong principle in the preparation of these charts, but the authorities there will, of course, know their own business best. My point is that they recognise the primary importance of agriculture in the economy of the State and the welfare thereof, and make this their first concern; while the officials in Britain leave it to the last and take it up as the fag-end of their work.

Agriculture is a robust occupation, but it is of the first importance in following it to observe and note everything there is to be seen about a countryside, and the object of the writer of this book will be attained if the reader rises from its perusal with a clearer knowlege of what he sees when he goes out across the fields "to view the corn and snuff the caller air." The study of any department of natural science is as refreshing as the playing of pibrochs to the spirit of a man weary of the effeminate music which pleases theatre-goers.

It may be necessary to add—what some may have already discovered— that in this enquiry the author has assumed that the reader is already familiar with the general outlines of Geology and the cognate sciences. It would be obviously out of place to take up room with details which can be found in any elementary text-book on the subject, as this volume purports to be only the practical application of the general science to a special department of human labour. For convenience of reference, however, some tables are given in the Appendix.

---

* "Field Operations of the Division of Soils," 1899, United States Department of Agriculture.

CHAPTER II.

ORIGIN AND FORMATION OF SOILS.

THE making of a soil can be watched in operation at any time by anyone who has the patience and power of observation to note when a new surface of rock or a new section of the ground is exposed.

In a general way soil is mostly the decomposed top of the rock,* more or less unwashed in the case of fertile fields, or else formed altogether of deposited washings as in the case of alluvial meadows. The depth to which decomposition or disintegration will penetrate downwards into solid rock when brought about by ordinary atmospheric agency is enormous in some cases. Leaving out of account the accumulation of rock wreckage from the action of frost on some of our hill tops, there appears to have been a very great degree of decomposition due to other disintegrating agencies in some of the more southern latitudes. In Alabama, for example, in the region of granite and other primitive rocks, it is not uncommon to find in railway cuttings and wells that ordinary disintegration has gone on down to depths of 30, 50, and even 70 or 80 feet, the débris yielding soils of excellent quality. Boussingault in one instance traced such a disintegration to a depth of more than 300 feet in a mine worked in syenitic porphyry.†

In Jersey the author has noticed the great depth to which the granite has been disintegrated in some of the road cuttings—as in that between St. Brelades and St. Heliers—and the exceptional fertility of the soil formed from this *in situ*, which, combined with the genial climate, has helped to make the growth of vegetables so successful there.

Indeed, from the subjoined table it may be seen that, as the materials contained in plants and soils are very similar to those in igneous rocks (*i.e.*, the most complex by analysis), the composition of a soil must bear at least some relation to the rock from which it

* Green: "Physical Geology," p. 111.

† Storer: "Agriculture in some of its Relations with Chemistry," Vol. I., p. 128.

was derived, and thus have present all the elements of fertility required by plants :—

IGNEOUS ROCKS	SOIL.	PLANT ASH.
Silica	Silica	Silica.
Alumina	Alumina	Alumina (traces in lichens).
Lime	Lime	Lime.
Magnesia	Magnesia	Magnesia.
Soda	Soda	Soda.
Potash	Potash	Potash.
Carbonic anhyd. ...	Carbonic anhyd ...	Carbonates.
Ferrous oxide... ...	Ferrous oxide ...	Iron.
Ferric oxide	Ferric oxide ..	Iron.
Phosphorus	Phosphoric anhyd....	Phosphoric anhyd.
Sulphur	Sulphur trioxide ...	Sulphur trioxide.
Chlorine	Chlorine	Chlorine.
Manganese protox. ...	Manganese	Manganese (traces).
Fluorine	Fluorine	Fluorine (grasses, &c.).
——	Bromine	Bromine (traces).
——	Iodine	Iodine (seaweed and seashore plants).

While on this point of the chemical composition of soils it is interesting to note what the actual ultimate percentages of the components are, and the following table of the analyses of several varieties of fertile soils will show this :—

	Insoluble Silicates and Sand.	Alumina.	Lime.	Magnesia.	Soda.	Potash.	Carbonic Anhydride.	Ferric Oxide.	Sulphuric Anhydride.	Chlorine.	Phosphoric Anhydride.	Organic Matter and Water of Combination.
1. **Sandy Soil**	92·52	2·65	0·24	0·70	0·02	0·12	—	3·19	trace	trace	0·07	0·49
2. **Sandy Loam (Dumbarton)** ...	78·30	2·60	0·34	0·28	0·17	2·22	—	4·27	0·10	0·14	0·38	9·05
3. **Loamy Soil**	81·26	3·58	1·28	1·12	1·20	0·80	0·92	3·41	0·09	trace	0.38	5·66
4. **Clayey Loam (Essex)**... ...	81·26	5·46	1·23	0·56	0·15	0·58	0·32	4·60	0·07	0·003	0·13	5·62
5. **Clayey Soil (Carse of Gowrie)**	61·20	14·04	0·83	1·02	1·44	2·80	—	4·87	0·09	0·01	0·24	11·25
6. **Marly Soil**	55·52	5·96	11·15	0·25	0·71		8·77	5·96	0·04	0·76	0·38	10·50
7. **Calcareous Soil (Salisbury)** ...	28·77	6·00	30·55	trace	1·03		23·91	3·31	trace	—	trace	6·33
8. **Humous Soil**	72·80	9·30	1·01	0·20	0·01		—	6·30	0·17	—	0·13	10·08

There is always a more or less intimate relation between the

top soil and the geological formation beneath, but this is seen better in some cases than in others. On the secondary and tertiary formations of England this relationship is exceptionally well exemplified,* and a map of these formations is generally also a very exact map of the soils, and *vice versa;* but where the "disturbing element" of the Boulder Clay occurs it requires some skill and experience to trace and unravel the complications introduced. Soil, indeed, is always a mixture of clay, quartz sand, and other disintegrated rock material, along with carbonaceous matters derived from the decomposition of vegetable and animal remains. From these last it gets its dark colour and the chief part of its fertility.†

Sedentary and "Transported" Soils.—It is customary in text books to treat of two kinds of soils—those which have been transported and those formed *in situ;* or in the words of Shaler, *soils of immediate derivation* and *soils of remote derivation.*‡ There is, however, no such thing as a "transported" soil in existence, excepting that which a farmer transports in his cart when levelling down or filling up irregularities about his fields, or a gardener transports in his wheelbarrow when he is making up his flower beds. The subsoil may be transported material, that is the mineral débris of rocks brought from a distance by the action of water or ice, though in the geological sense of the term it is as much a rock or formation as is sandstone or chalk; and we may make a possible exception in the case of some alluviums which have been derived from the washings of soils already formed higher up the streams, as in the case of the Ouse, in Yorkshire, where the "warp" forms a soil immediately after settling down; but in all other cases the soil has been formed where it now is by the weathering of the hard rock on the spot, or the further weathering of the débris of former action which has accumulated to form a surface formation or "drift," aided by the formation of the organic part, or humus, and by the action of the agents now to be here described.

It, of course, very much depends on what one includes under the term "soil," but in this work and others of a similar nature it is limited to the cultivatable surface, or the top layer, in which and on which plants can grow. In this limitation, therefore, it can

* Page: "Economic Geology," p. 36.

† Dana: "Mineralogy," p. 465.

‡ McGee: "Geology and Agriculture," p. 4. *Iowa State Hort. Soc.*, 1884.

easily be understood that it is quite correct to say that all soils have been made on the place where we now find them. The materials out of which they have been made may have been transported, probably have been so, but that is a very different matter indeed—as different as is a coat on a man's back from the original wool on a sheep's back out of which it has been made. Recollecting for the moment that the soil proper is only the few top inches of the surface, that the subsoil comes below that, and the "rubble" and solid rock below that,* we can understand that every soil was formed where we now find it, out of the material of which the subsoil is composed *plus* organic matter.

Chemical Action.—The process of disintegration from a chemical point of view may be taken conveniently as beginning with the action of the oxygen of the atmosphere on the oxidizable minerals—or their components—in the rocks.

Thus oxygen unites with the iron in mineral materials and forms rust or oxide, and in so doing breaks up the cementing power of the same, and the broken up material becomes detached as débris. Where the iron already existed as a protoxide the process is carried on further into the peroxide form and in the presence of water into the hydroxide form.

Iron, of course, is not the only substance that oxidizes, but it is one of the most common and most prominent, while the peroxide form very readily parts with its extra oxygen to any other oxidizable substance it comes into contact with, and for this reason it has sometimes in this connection been called an "oxygen carrier." An example of the process of oxidation may be seen in ordinary ploughing or cultivation. The iron oxide in the lower layer of the soil proper becomes partly deoxidized, and when this is turned up to the air its browns and yellows are light-coloured or pale. These visibly change to darker colours in a few days, *i.e.*, the protoxide becomes peroxide—this being one of the important processes forming part of the melioration or weathering of the freshly turned-up furrow.

Metallic protoxides in general are thus changed into peroxides, and, since water is always present, into hydroxides; ferrous oxide (FeO) combined with silica (silicate of iron) being changed into ferric hydrate ($2\,Fe_2O_3 \cdot 3\,H_2O$), as is exemplified in the soils of the Upper Greensand at the Woburn experimental station of the

* Fig. 5, p. 124.

Royal Agricultural Society of England. By this process the texture of minerals containing ferrous silicate—as for instance many felspars, certain micas, hornblende and augite—is loosened,* and thus weathering and denudation is promoted. From changes of this nature we are able to infer that iron is one of the most valuable ingredients of a soil. It does not enter very largely into the composition of plants, but the part it plays in the first formation of soils and in every subsequent process in the same—chemical and physical—is of the first importance. Practical farmers, who may know nothing of the scientific aspects of the question, have found that red and brown are colours nearly always associated with good soils, and reckon these as points in favour of the same—other things being equal—and these colours are mostly due to a large proportion of iron oxides being present.

Another chemical process which takes place in the formation of soils is of great importance in the weathering down of mineral matter. This is the conversion of sulphides into sulphates by combination with oxygen. Many rocks contain metallic sulphides, such as the clay-slates, bituminous marls, and clays,† and these on being opened up to the action of moist air have the metallic sulphides converted into sulphates, which can be more or less washed out by water, leaving the rock porous and cellular, and thus easy to break up into fragments.

The salts of lead and copper are poisonous in soils; also the sulphate of iron; also alum (hydrous sulphate of alumina and potash) in excess; and even common salt (chloride of sodium) ‡ in large quantity.

The same process may occur in the deeper layers of the soil when these are turned up and exposed to the air, as also in the mud taken out of swamps and ponds; stuff which is not fit to support vegetation until mellowed by exposure to the air. In the case of gas-lime used as a top-dressing the process is the same; there is a large proportion of sulphide and sulphite of lime present, which must oxidize into sulphate before crops will grow on the soil to which it is applied.

Kaolinization.—We now come to study one of the most important chemical processes in the formation of a soil, that of *kaolinization* or the formation of the clay or kaolin. Its importance

* Wahnschaffe: "Scientific Examination of Soils," p. 18.

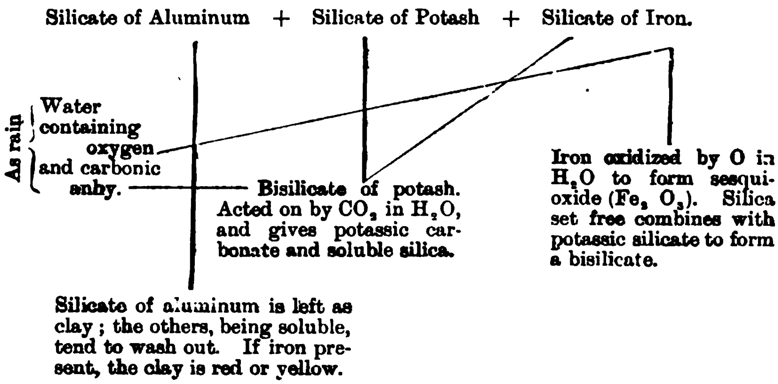
† Ibid., p. 18.

‡ Ansted: "Applications of Geology, &c.," p. 22.

lies in the fact that in the great majority of soils the bulk of their composition is made up of sand and clay, these, in fact, forming the body of the soil on which much of its physical properties depend, as also do its farming characteristics as regards its "lightness" or "heaviness," suitability for growing roots and barley, or beans and wheat, for folding sheep thereon, for keeping in grass or making arable, and so on; while the other components are generally present in comparatively small quantities, the "elements of fertility" sometimes only in traces.

The process of *kaolinization* takes place, generally, where rain water containing carbonic acid gas comes into contact with the silicious minerals rich in alkaline bodies such as potash, soda, lime, and magnesia. These are converted into carbonates and bicarbonates, which, with a proportion of separated gelatinous silica are washed out by the water, leaving the hydrated silicate of alumina—kaolin, pipe-clay, or china clay—behind. This is known as Forchhammer's theory,* and in the case of orthoclase felspar the actions and reactions may be represented thus:—

WEATHERING OF ORTHOCLASE FELSPAR INTO CLAY.



The oxygen first attacks the iron, next the carbonic anhydride acts upon the newly-formed potassic bisilicate; this tends to get washed out, and clay or hydrated aluminic silicate ($Al_2O_3 \cdot 2SiO_2 + 2H_2O$), more or less impure, remains.

It is found that in this process a considerable quantity of quartz-flour is set free and not washed out under natural conditions, and accurate chemical investigation has shown that in soils the content of clay has formerly often been put too high, as part of

* Wahnschaffe: "Scientific Examination of Soils," p. 19.

the "clay" separated by elutriation was really quartz-flour in the finer portions.*

Usually pure kaolin or "kaolinite" is an amorphous white powder in appearance, with a soapy feel and plastic on being wetted, but under the microscope the uninjured particles are seen to be hexagonal plates, amongst which are a few rhomboidal ones,† thus following the laws of crystallization where the conditions of formation have been favourable.

In the actual process under natural conditions there is, of course, very little pure clay formed, because the other ingredients of the minerals do not always wash out, while many other bodies are in juxtaposition and thus get washed into mixture with these—such as sand, stones, limestone, humus, iron oxides, and so on—so that what may be from a farming point of view "a stiff clay soil" may really not contain more than 30 per cent. of pure clay or kaolin. Even clay that is good enough for brickmaking—red or yellow in colour when burnt—contains only say 80 per cent., the rest being "impurities," but bodies which are of the utmost value in helping to make up a soil.

In exceptional spots, however, there are deposits of pure clay formed; the kaolin, china clay, pipe-clay, or porcelain clay of the arts are examples of this, in which the silicate of alumina is free from all colouring or other extraneous matter, and is thus white in colour. Deposits of this occur on Dartmoor, in many places in Cornwall, and at Bovey Tracey, all derived directly or indirectly from the felspar of granite or its near relative pegmatite, while porphyry and gneiss furnish other moderately pure varieties. Besides these there are many almost pure clays of various geological ages in different parts of the world known to geologists, while every brickwork, pottery, and similar factory is the outward and visible sign of a workable deposit of clay of lesser value, clayey soils again being another class of formation in which this kaolin or hydrated silicate of alumina is the characteristic.

But a great many other mineral bodies besides felspars are composed of silicates—such as hornblende, augite, and olivine—and these yield, by their decomposition, not only kaolin, but also compounds of lime and magnesia, hydrous peroxide of iron (göthite), hydrous sesquioxide of iron (limonite), and hydrous silicate of iron and potash (glauconite), &c. Owing to the presence of so many

* Wahnschaffe: "Scientific Examination of Soils," p. 83.

† Dick: "On Kaolinite," p. 16. *Mineralogical Mag.*, 1888.

complex silicates—alkaline and metallic—in minerals like those just mentioned, rocks like diorite, diabase, melaphyre, and others of a similar nature, generally decompose into green and brown clays.*

Below is given the percentage composition of clays derived directly from the decomposition of granite, basalt, and greenstone (dolerite), while a table of the composition of several typical clays is also given† :—

	Granite.		Basalt.		Greenstone.	
	Unaltered.	Weathered.	Unaltered	Weathered.	Unaltered.	Weathered.
Silica	73·1	74·6	44·4	42·5	51·4	44·5
Alumina... ...	10·5	12·0	12·2	17·9	15·8	22·1
Lime	...	...	11·3	2·5	5·7	1·4
Magnesia ...	1·1	0·8	9·1	3·3	2·8	2·7
Soda	1·8	0·4	2·7	} 0·2 {	3·9	1·7
Potash	9·0	4·9	0·8		1·6	1·2
Iron protoxide ...	...	...	12·1	...	12·9	...
Iron peroxide ...	3·2	3·2	3·5	11·5	2·5	} 17·6
Manganese oxide	...	...	...	...	0·5	
Water	0·5	3·2	4·4	20·4	1·7	8·6
Other bodies, and loss	0·8	0·9	...	1·7	1·2	0·2

CHEMICAL COMPOSITION OF CERTAIN CLAYS.

	Eocene.	Cretaceous.	Jurassic.	Carboniferous.		Silurian.	Miocene.
	Pottery Clay, Poole.	Fuller's Earth, Nutfield.	Kim Clay, Wilts.	Fire Clay, Stourbridge.	Red Tile Clay, Broseley.	White Soapy Clay, Horderley.	Pottery Clay, Bovey.
Silica	48·99	57·0	55·16	73·82	64·06	45·48	47·00
Alumina ...	32·11	10·3	21·88	15·88	20·60	23·52	48·00
Lime	0·43	—	Sulphide 2·62	trace	0·12	Carb. 11·10	—
Magnesia ...	0·22	3·0	1·51	trace	0·04	1·44	2·00
Potash	3·31	—	2·22	} 0·90 {	0·91	2.15	—
Soda	—	—	2·40		0·44	0·54	—
Protox. Iron	2·34	} 6·7 {	4·17	2·95	0·32	1·76	} 1·50
Perox. Iron ...	—		—	—	6·84	—	
Protox. Mag.	—	—	—	—	0·09	0·07	—
Titanic Acid	—	—	2·19	—	0·62	—	—
Water	11·99	23·0	7·25	6·45	5·85	13·88	1·50
	99·39	100·0	99·40	100·00	99·89	99·89	100·00

* Prestwich : "Geology," Vol. I., p. 50.
† Ibid., pp. 27 and 53.

Basic volcanic rocks generally, such as dolerite, andesite, &c., are liable to decompose—as also in a lesser degree trachytic lavas and scoriæ—into light coloured clays. The village of Bianca, in the volcanic country near Rome, derives its name from the whiteness of the soil, produced by the kaolin resulting from the decomposition of trachyte.*

Generally speaking, granite, gneiss, basalt, clay-slate, and some other metamorphic and igneous rocks yield clay soils on decomposition,† while augite and hornblende decay into a brown, ferruginous, sandy loam.‡

Some diorites again weather into a soil exactly like an accumulation of sand and boulders formed by a mountain torrent.§

Solvent Action of Water.—The water supplied by the rain percolates into every seam and crevice, and even soaks into the solid matrix of rock itself, dissolving out portions of soluble salts, and even of material which is usually considered insoluble, for it is remarkable that everything is soluble to some small extent in water, especially if reduced to a fine state of division ; thus, pure water has been found to digest 0·4 to 1·0 per cent. of the weight of powdered felspar, hornblende, chlorite, serpentine, and natrolite in a week.||

The permeability of solid rock to water, air, and even to the roots of plants, is greatly enhanced by the occurrence, in many kinds of formations, of joints or fissures in the mass of the same. Many beds of limestones, sandstones, &c., are naturally full of these seams, and which are made use of by quarrymen to insert their wedges for the purpose of wrenching off blocks. Where the rock is near the surface, the disintegrating agents make full use of these crevices, and very soon accumulate a mass of wreckage and decomposed material.

The power of water to soak into some of the hardest rocks is exemplified in the case of granite. The fragments or crystals of mineral are not perfectly joined together, so that it is permeable to water; 100 lbs. of rock being able to absorb 0·4 lbs. of water,¶ while, of course, this water has solvent power, and is freezable.

The solving power of pure water is considerable in the case of

* Prestwich : "Geology," Vol. I., p. 52.
† Ansted : "Applications of Geology, &c.," p. 17.
‡ Jukes-Brown : "Physical Geology," p. 73.
§ Green : "Physical Geology," p. 113.
|| Johnson : "How Crops Feed," p. 128.
¶ King : "The Soil," p. 39.

some rock forms of simple composition, such as gypsum, rock-salt, limestone and dolomite: gypsum, for instance, dissolving at the rate of 1 to 400 parts, forming "permanently" hard water; limestone 1 in 1,000 and yielding "temporarily" hard water; while salt is well known for its extreme solubility. Such instances as these exemplify how easily some rocks become disintegrated, how plant food is easily supplied; but also, unfortunately, how easily soils may become leached and lose some of their valuable constituents.

But the solvent power of water is immensely enhanced if it contains the gas called carbon dioxide (CO_2) in solution. This it gets either from absorption from the atmosphere as it falls in rain, or from decaying vegetation and humus in the top soil as it filters through. Water with this gas in solution has a great affinity for limestone (calcic carbonate), causing it to dissolve. When it comes into contact with mineral material containing limestone—though not a "limestone" rock in the ordinary sense of the term—it immediately dissolves it out, leaving the bulk in a collapsible or friable state, equal again to so much débris. The same thing occurs in connection with various other soluble ingredients of minerals. For instance, in an experiment in which a pound of phonolite was powdered and put into water saturated with carbonic acid gas at three atmospheres, the following kinds and quantities of material were dissolved out* :—

Carbonate of soda	22·5 grains.
Sulphate of soda	4·8 "
Carbonate of lime	4·5 "
Chloride of sodium	2·0 "
Sulphate of potash	1·7 "
Carbonate of magnesia	1·1 "
Silica	0·5 "
Phosphoric acid and manganese ...	traces
	37·1 grains.

In addition to carbonic acid gas in the water in the soil or surface material generally, there are—as soon as any vegetation has grown and then decayed—a certain proportion of what are called organic acids formed, such as humic, ulmic, crenic, geic, &c.; acids which have a tendency to unite with any alkaline bases they are carried into contact with, and thus form soluble salts with the potash, soda, &c., occurring in minerals; thus, again, helping to

* Johnson: "How Crops Feed," p. 129.

denude the surface of rock material. In this way water on the surface, or in crevices, or even that which soaks through the pores of solid rock has its solvent power greatly intensified from the presence of these acid bodies in it; and while the resultant salts may be redeposited somewhere, or form part of the subsequently-formed soil, their formation means the loosening and breaking up of every rock surface they come into contact with.

But the dissolved salts are not all, or even mostly, redeposited at or near where they are formed and set free. In the soil mass those formed are no doubt largely retained by the sponge-like action of the humus; by the chemico-mechanical action of adhesion, capillarity, &c.; by possession of a small degree of solubility (as with the phosphates), as against a great degree of solubility (as with the nitrates), and so on: but a large total proportion are carried downwards and seawards in every ditch, stream, and river. It is calculated that the average amount over the whole world carried down by rivers to the sea *in solution*, per annum, is equal to 100 tons of rock to every square mile*—in England alone, 143·5 tons—the salts being in about the following proportions:—

Calcium carbonate	50 per cent.
Calcium sulphate	20 "
Silica	7 "
Magnesium carbonate	4 "
Magnesium sulphate	4 "
Sodium chloride	4 "
Other alkaline carbonates and sulphates	6 "

As the silt *in suspension* is reckoned to be at least five times as much, it follows that, on the average, 600 tons of material is removed from every square mile, per annum, and carried out to sea.

Action of Running Water.—But besides the solving power of water containing carbon dioxide gas, and other acids in solution, there is the mechanical grinding or eroding power of the same when running on the surface in streams, more especially when it contains solid material varying in size from fine sand up to large boulders. This power has been sufficient to wear out whole valleys, canons, and even the whole surface of the exposed land has been subjected to this action. The eroded material thus worn out by running water is, of course, largely carried out to sea and deposited opposite

* Dana: "Manual of Geology." p. 657.

the mouths of the rivers as new formations under the water. A proportion of it, however, is deposited in the valley bottoms as alluvium, or at the mouths of the streams above tide mark as estuarine accumulations, each with their own varieties of top soil.

The rain, in falling on a wasting rock surface, sweeps up the scales and fragments peeled off by the various agencies, and washes them downwards into the nearest stream. This stream acts as a mill in which fragments of every size roll and grind against each other and the banks and bottom, and make more débris in the shape of sand and gravel and even fine earthy matter, all of which are equal to the wearing away of the higher land to give material for the making of level soil lower down, while the débris carried out to sea is making new formations on its bottom.

The whole surface soil is of course subject to the same washing and eroding power, but the total quantity of the soil never becomes appreciably less on that account. This is due to the fact that the process of erosion is so slow (calculated at one foot deep over the Thames Valley in 1,000 years, as noted above)—while the renovating agents are at work making good deficiencies in the shape of vegetation and the melioration of more subsoil from below into soil proper—that there is no visible or noticeable wasting of surface in an ordinary life-time.

Sometimes soils are formed by the actual "rain-wash"; that is a current of water flowing over the land washes the débris down into the hollows and deposits it there—the predominating feature of such a deposit being that it is local in origin and the stones contained in it are angular.* This rain-wash unfortunately sometimes destroys a soil after it has been made and lasted for ages. The vegetation acts as a protective covering, but once this is removed, then the damage done by the rain-wash may be considerable. In our own islands, where the land is under cultivation, there is a notable increase in the amount of silt washed off into drains, ditches, or ponds, as compared with that off grass land. But in other countries, where the rains are excessive or torrential, the removal or subsidence of the "soil-cap" is sometimes on a disastrous scale. There is scarcely a county in Virginia, the Carolinas, Kentucky, Tennessee, and Mississippi where it is not possible to find a number of areas aggregating from 300 to 500

* Goodwin and Austin: *Quart. Jour. Geol. Soc.*, Vols. VI., p. 94, and VII., p. 121.

acres where the true soil has been allowed to wash away, leaving exposed to the air either bare rock or infertile subsoil,* and all this has happened as the result of clearing off the forest and breaking up the land for cultivation. Again, there are tracts of land in the Himalayas where, at the cost of the primeval forests, tea gardens have been established on the slopes, and where, after a few years, the tea bushes have been left starving on the almost bare rocks owing to the soil having been washed down into the valleys.†

Action of Frost.—Perhaps, however, the principal eroding power of water is exerted when it is in the form of ice. The water which has percolated into the seams and crevices, and soaked into the solid mass of mineral material, when subjected to the action of a low temperature, as during frost in winter time or all the year round in an arctic region, freezes, and in doing so expands about one-eighth in bulk. This expansion is due to irresistible molecular force, and the result is that the surface material is peeled off in flakes and chips, while on a larger scale slabs and chunks are riven off, and even a huge crag may be splintered up by this agency. The débris or degraded material accumulates very rapidly where this agent is at work, and, if there were no transporting agencies, it would accumulate where it is formed, making up a coating of material which would be the basis of the mineral matter of a soil. When the thaw comes, however, the rush of water down-hill tends to carry part of it seawards: part of it only, however, reaches the sea, for some remains where it was formed—or near where it was formed, unless and except there has been an actual débâcle or glacier action. As an example of this work where there is no rain-wash, there are found, on some of the higher hill-tops in England, accumulations of several feet in depth of the wreckage from the action of the frost.‡

Action of Lichens and Mosses.—Succeeding the action of these physical and chemical agencies in the earlier stages, and in conjunction with them ever since, there has been the breaking down and building up of soil material by the growth and decay of plants. Wherever a bare face of rock or stone is exposed it becomes immediately covered over by some of the lower forms of vegetation,

* Shaler: "Origin and Nature of Soils," p. 332. *United States Geol. Sur. Ann. Rep.*, 1891.

† Ball: "On some effects produced by Landslips and Movements of the Soil-Cap," p. 7. *Proceedings: Royal Dublin Soc.*, April, 1883.

‡ Gaye: "World's Great Farm," p. 25.

such as lichens and mosses. These have the power of dissolving out of the solid mineral matter, by the exceptionally strong acid-secretions of the roots, the elements of fertility necessary for their growth, and this along with the carbon assimilated by the green parts from the atmosphere is enough for the full development of the same. Eventually the plants die and decay, and the material thus added to and mixed with the mineral débris supplies the humus or organic part of the soil, which thus becomes fitted for the growth of a higher or more developed class of plants.

These first lichens appear as "stains" on the surface of the rock or stone. They require more mineral food than any other plants, and can eat it out of the rock better than other plants because of their greater root-acidity, while their presence keeps the surface of the rock always moist and thus helps on the action.

Lichens have been found on limestone rocks to contain half their weight of oxalate of lime, while club-mosses have a large proportion of alumina in their composition—an ingredient not found in plants of a higher order, so thus these plants of a lower order are specially suited to attack the raw mineral matter.

Lichens will attack not only the softer rocks, but lava, granites, slates, crystalline quartz, &c., if moist—in fact every stone will yield to their action. A good example is found in the case of the "violet stone" of the Brocken, which is simply granite covered by a thin scale of scarlet lichen. The decay of this forms a film of soil on which two kinds of large brown lichens thrive, eventually forming soil good enough for pines to grow on.*

This action may also be seen in the growth of lichens and mosses on the tile roof of a farm homestead. The grey and the yellow lichens first take root on the damp surface of the baked clay, sending their rhizines into the seams and pores of the same, and dissolving out mineral nutriment for themselves, probably by means of the lichenic, chrysophanic, and other acids plentifully developed in their tissues; and, aided by the moisture and the frost, splintering up and decomposing the surface of the same. The decay of these first plants—or the first grown part of each—supplies a little humus or peaty material on which mosses such as *Sphagnum palustre* and *Hypnum cuspidatum* can take root, which, in their turn, partly or wholly die and decay, and thus an inch or two of soil is formed in patches on the roof in the course of a few years; a soil proper in every sense of the term—

* Gaye: "World's Great Farm," p. 33.

though of a peaty or humous nature—and one on which plants higher in the scale, such as grasses and others, will take root and grow. The accumulation of such is no doubt aided by the gathering of blown dust, but, on the other hand, the great washing power of the rain on a smooth steep surface like a house roof, will more than counterbalance this.

Action of Acid-Secretions of Roots.—The acid-secretions of the growing roots of all plants have a very great effect on the undecomposed mineral or rocky material of the soil: it is most active in those plants of a low organization like the lichens and mosses as just mentioned, while in the case of the common farm crops it has been shown by Dyer to be equal to a one per cent. solution of citric acid acting in a manner analogous to the gastric juice in the stomach of an animal. What this acidity can do may actually be seen by a very simple experiment. A slab of polished marble is taken, covered with a layer of soil, sown with beans, and kept watered. The beans will grow in the usual way, and after their growth has ceased, if the earth be removed from the slab and the latter washed, it will then be seen that it is etched all over with a network of marks caused by the roots and fibres running along the surface of the marble and dissolving out a proportion of the limestone. In a farm crop this mineral food material is, of course, partly removed from the soil, but in a state of nature everything is returned in the decaying plant, thus helping to make up the bulk of the humus.

That the amount of material dissolved out of the solid rock substance is not immaterial, but is, indeed, something of importance, is borne out by the following figures, first compiled by Dietrich*:—

Kind of Plant.	Mineral Matter Dissolved.	
	Variegated Sandstone.	Basalt.
Lupine	·6080 grammes.	·7492 grammes.
Pea	·4807 ,,	·7132 ,,
Buckwheat	·2322 ,,	·3274 ,,
Vetch	·2212 ,,	·2514 ,,
Wheat	·0272 ,,	·1958 ,,
Rye	·0137 ,,	·1316 ,,

* Stockbridge: "Rocks and Soils," p. 112.

The above quantities are comparatively so great that they are actually much in excess of the amount which would be disintegrated by the ordinary weathering process under the same conditions. A definite comparison with the lupine and pea is as follows, taking the pea at a total of ·8 grammes :—

	Mineral Matter Dissolved.				
	Potash.	Lime.	Magnesia.	Phosphoric Acid.	Totals.
Weathering process ...	·0388	·4516	·0892	·0356	·6152
Pea	·0684	·5218	·1230	·0868	·8000
Lupine	·0920	·4625	·1332	·0971	·7848

Action of Growing Roots.—But besides the chemical action of roots in making soils, there is the mechanical action exerted by them in growing and enlarging in size. They act like wedges, for having once obtained entry into cracks or seams they continue to grow, and thus split up rocky material quite easily. This is true of all roots, more or less ; but use is made of this power directly by mankind in various parts of the world. Thus the prickly pear (cactus) is grown on lava rock in some tropical and sub-tropical districts for the express purpose of making it into soil by its power of growing in the cracks, and thus splitting up the material more quickly, and dissolving out a large part by its greater secretion of acid and need of mineral food.* In the ordinary course of weathering and soil formation lava is converted into a soil—and one of extreme fertility—in a century, but it becomes a matter of a few years when treated as above.

Action of Microbes.—Besides those acids peculiar to the roots of plants, and which enable plants to partly dissolve their own food out of the mineral particles of the soil and thus further the process of disintegration, there are those developed by microbe life. Living in the soil proper, and as deep down as 18 inches in that of deep staple, are countless "numbers of microscopic forms, which, feeding on the dead tissues of plants and animals, evolve large quantities of carbon dioxide, nitric and other acids, which in their turn become corrosive agents."† The bacteriology of the soil is a subject that

* Gaye : "World's Great Farm," p. 35.
† King : "The Soil," p. 19.

has not yet been thoroughly studied except by a very few investigators,* so that the definite and particular part played by the different forms cannot be fully here given, but one or two cases may be instanced by way of example. The conversion of ammonia—or rather of the nitrogen of the organic material – in the soil into nitric acid is brought about by two groups of microbes, one converting it into the halfway stage of nitrous acid (NO_2), and the other carrying it into the nitric acid stage (NO_3).

There are many species of these nitrifying bacteria, and the two groups just mentioned are classed as *Nitroso-bacteria* and *Nitro-bacteria*.† The former (of which *Nitrosomonas Europæa* is a type) is the most active, and its activity depends principally on the presence of calcium carbonate to take up the nitrous acid formed, or to neutralize the acid combined with the ammonia which it oxidizes—as when ammonium sulphate is applied to the soil. The latter group takes up the nitrites formed by the other, and carries them on to the greater oxidation of the nitrate stage. The *Nitro-bacteria* of Quito earth are believed to be among the primary agents in forming the deposits of nitrate of soda on the western coasts of South America, while both groups are always present in the soil and in fermenting dung-heaps, carrying on their life work of oxidizing the nitrogen of ammonia salts.

In connection with this it may be here mentioned that the soil has little or no power of fixing nitrates; they become very quickly washed out into the drains. In practical farming it means that ammonium sulphate or chloride will give more lasting, if slower, results than sodium nitrate as a manure; that nitrate must only be applied to a growing crop ready to soak it up; and that farm-yard dung should be applied as fresh and un-rotted to the land as possible.

Besides these nitrifying organisms there are a host of others which have been isolated and are known, producing various changes on soil material to fit it for the growth of plants. The above-named groups of microbes can only tackle the salts of ammonia, but these do not exist until they have been formed from organic matter by another lot of microbes such as the *Micrococcus ureæ* and the *Urobacillus Pasteuri*, which convert the urea of dung into ammonium carbonate. Other microbes act in other ways, as

* Young: "The Nineteenth Century," Nov., 1899, p. 782.

† Bowhill: "Bacteriological Technique and Special Bacteriology," p. 232.

for instance the *Kladothrix ochracea*, which acts on the carbonate of iron in water and causes a deposit of the oxyhydrate as yellow ochreous matter, choking up drains and ditches very badly on some farms; the nitrogen-fixing bacteria of the nodules on the roots of the *Leguminosæ* (such as *Bacillus radicicola*, *Rhizobium leguminosarum*, and *Bacillus tuberigenus*); and so on with many others.

The transformation of plant tissue into the humus or organic portion of the soil is largely, of course, due to microbic life, but the decomposition is fundamentally one of oxidation. The material mostly consists of carbon and hydrogen, which become carbon monoxide (CO), carbon dioxide (CO_2), and marsh gas (CH_4); and of albuminoids, which become ammonia (NH_3) and nitric acid (HNO_3). In addition, there are formed humic, ulmic, and geic acids, which on further oxidation become crenic and apocrenic acids—all of which, however, are now believed to owe their formation and changes to the action of microbes.

Action of Sun's Heat.—Even the exposure to the sun's heat has some effect in weathering down mineral material. Wherever a clay rock or even a harder formation is exposed to the blazing sunshine it becomes dried up, shrinks and cracks, and thus shatters into crumbly material, giving easier access to the oxygen of the atmosphere and other weathering agents. This applies in an accentuated degree to rock material built up of several minerals. These minerals expand and contract in different degrees, so that the alternate heating and cooling of the same tends to strain and rupture the mass, and thus helps on the conversion of rock into soil. This, of course, happens more in tropic and sub-tropic regions where there is a very great range of diurnal temperature, but even in this country the effect on the surface of bare rock is considerable; while, as an example, at Cape Ann in Massachusetts there are hundreds of acres of bare rock surface completely covered with splinters of stone which have been separated from the mass beneath by variation in temperature.* The seasonal temperature exerts an influence to a depth of at least 60 feet, and possibly to 100 feet in some cases, while the daily range reaches only to some 3 or 4 feet; yet the latter may have the most effect on shattering a rock on account of its action being more sudden, just as a lamp chimney may break from a sudden screwing up or down of the flame, though the same funnel would stand red-heat or freezing

* Merrill: "Rock Weathering, &c.," p. 181.

point uninjured if the change were made gradually. A daily variation of 150° F. is common in hot climates, and this alone is enough to split boulders into pieces.* Even the surface of the ground in clay districts cracks exceedingly in summer time—cracks of four inches wide and four or five feet deep being quite common —and these must help much in furthering the weathering action, while they give access to seeds of all sorts to lie dormant in the depths for years. This cracking from the sun's heat is apt to displace the pipe tiles of the drains on clay soils in the South of England, while it has rendered draining impossible in India. The drying up of the surface from the evaporation caused by the sun's heat promotes the action of capillarity in the soil. The water which thus rises from below by capillary action brings with it many salts in solution, which are deposited on the surface or in the surface layer of the soil as an efflorescence. This, of course, is re-dissolved when rain comes again, but the travelling up and down of these compounds of various salts must have a certain amount of effect on the soil or subsoil of a weathering nature, though we cannot state what that exactly is or reduce it to a chemical equation.

Action of Wind.—Even the wind plays a part in the formation of soils. In some regions where there are exposed sandstone rocks, the driving of the loose sand against these is sufficient to wear them still further down, in fact the erosion is as great as that due to frost, as exemplified in the Brinham rocks, near Harrogate. On the other hand, the drifted dry dust and sand is spread over the surface somewhere, sometimes at the distance of many miles. For instance, the sand of the Sahara has been detected in the south winds blowing in Southern Europe; while the dust from the eruption of Heckla, in Iceland, in 1875, was carried as far as Norway. A more notable instance was the eruption of Krakatoa, in the autumn of 1883. The dust of this was believed to be carried right round the world, and to be the cause of the lovely sunsets of that period; while at a distance of 830 miles from the source, clouds of dust fell on the decks of vessels, accumulating at the rate of an inch per hour.†

In a lesser degree as regards distance, but in a greater degree as regards quantity of material, dust is being driven about by the wind, so that the surface material tends to thus get mixed up and

---

* Stockbridge: "Rocks and Soils," p. 95.
† Merrill: "Rock Weathering, &c.," p. 298.

carried about, or accumulated in hollows. On the prairies this driving of the soil becomes a perfect nuisance. When the turf is broken up, "backset," and sufficiently rotted away, the black soil left is of such a fine, pulverulent, fluffy nature, that it is easily blown about by the wind. It accumulates in the hollows, and drifts about the houses and roadways like "black snow," in spring, before the crops have got a hold. Strange to say, rolling intensifies the trouble, as it increases evaporation and the wind velocity at the surface;* and the use of corn-drills with presser-wheels behind has had to be adopted to obviate the trouble.

At home, there are many sandy fields round the sea coasts which have to be kept permanently in grass, because if ploughed up they would be completely denuded of the top soil by the wind, and the material be deposited further along, possibly to injure the next field. The famous Culbin Sands, in Morayshire, at the mouth of the Findhorn, is an example of the power of wind to drift material from one part and pile it up to make a new surface—though not a soil—in another place. On the Lincolnshire Wolds and on the coast of Norfolk, the light and sandy soils are often blown away by the equinoctial gales, and a field near Cromer was once sown three times, and failed then, as the soil was carried off completely.†

Action of Earthworms, &c.—In his work on "Earthworms" Darwin has shown that in the British Islands, and in many other regions of the earth, these lowly animals have done an immense deal in the modification of raw soil material and the formation of the mould or humous (organic) part. Put briefly, their action is as follows:—They live on the humus or vegetable remains in or on the soil, consuming large quantities of the finer material and ejecting the bulky refuse of the same on the surface in the shape of the well-known "worm casts" which annoy lawn keepers. Darwin found that these accumulated in average cases in sufficient quantity to make nearly one inch in depth of fine surface mould every five years on undisturbed pastures.‡ This does not go on indefinitely, of course, because there is a certain amount of waste from surface washing and from decay of organic material, while, when a few inches are accumulated, the worms are

* King: "The Soil," p. 202.

† Gaye: "World's Great Farm," p. 46.

‡ "Vegetable Mould and Earthworms," p. 171.

partly working the same material over and over again, but it certainly is the case that our soils proper (of a few inches in depth in contradistinction to the subsoils) have been largely made or modified by the action of earthworms from the raw mineral and vegetable débris forming their basis.

Darwin was not the first to point out the part played by worms in the making of the soil, for Hutton had done so 130 years ago; as a quotation of his own words will show, written when he was farming his own estate of Slighhouses, in Berwickshire, between 1752 and 1768. "In the first place a wood maintains a multitude of animals which die and are returned to the soil; secondly, it sheds an annual crop of leaves which contribute in some measure to the fertility of the soil; and lastly, the *soil thus enriched with animal and vegetable bodies feeds the worms, its proper inhabitants, which penetrate the soil and introduce fertility as they multiply.*"*

Worms are not found everywhere, however, and it is a curious fact that while they are plentiful in the states and provinces which are situated on the eastern old rocky formations in North America, they have not been met with on the prairies.† Now the prairies, again, yield soils of phenomenal fertility, but it is held by those who have studied the matter that these exceptional soils have been produced by the accumulation of the ashes of countless prairie fires, in some places, no doubt, on a basis formed of the silt which has accumulated on the bottom of former lakes—as in the Red River Valley and adjacent region—but in others directly on the yellow clay subsoil which underlies much of the prairie land.

Drummond, again, has shown that in tropical Africa this work of making up and mixing soil material is performed by the white ants, or termites, which devour every particle of dead, and even living, vegetable matter, and which is eventually—as part of their "hills," roads, or own bodies—wasted down again to form soil material.‡

The same thing takes place on a smaller scale in some places in Ireland. The ants love warm, dry sand or peat, and work over rock or stone and cover it with fine soil; and a colony will cover from two to three square feet every year and move on to a fresh

---

* Melvin: "Hutton's views of the Vegetable Soil or Mould, and Vegetable and Animal Life," p. 472. *Edin. Geol. Soc. Trans.*, 1887.

† Gaye: "World's Great Farm," p. 75.

‡ Drummond: "Tropical Africa," p. 154.

piece, while the grass grows on the mounds they make, and thus a turf is formed over a stone surface.*

Even the action of moles in the original making of a soil out of the subsoil and mixing up of material has been of considerable account, though we very much object to their operations now on cropping land or pastures where reapers and mowers require to shave the surface, but in bygone ages they must have worked and re-worked the whole of the soil over many times in the spots they frequented—that is, in humous places where worms were plentiful. All other burrowing animals must have helped in the same way, while in some cases abroad the work done in this way must have been enormous. Ants, moles, gophers, woodchucks, prairie dogs, marmots, &c., have all been workers in this way, turning up and

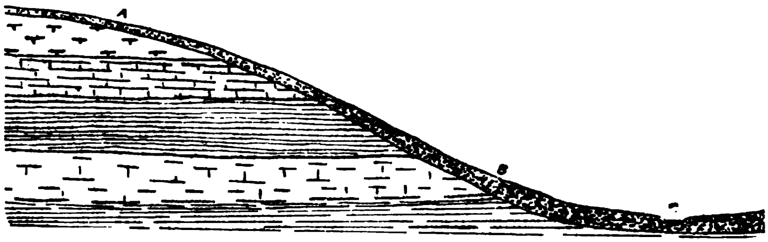


FIG. 2.

a—Poor thin stony soil. *b*—Good deep loamy soil. *c*—Stream.

mixing the soil and subsoil. Marmots, for instance, on the Caspian steppes have turned over and brought to the surface about forty inches in depth of earth all over the country in a few years,† thus practically carrying out subsoiling, trenching, and cultivation in an unequalled way.

The variations in the nature of the surface soil within a limited area—independent of the subjacent strata—has been very largely brought about by the action of earthworms and these burrowing animals just mentioned, aided by the action of the surface-wash of the rain water. It is a common experience to find, for instance, that the fertility and physical characteristics of the soil at the bottom end of a field are very much better than those at the top. (Fig. 2.) The reason is that the worms and other animals by continually

* Gaye: "World's Great Farm," p. 83.

† Stockbridge: "Rocks and Soils," p. 130.

bringing the finer material to the surface, have brought the same within the influence of the rain-wash; and the continual tendency of the water to run down-hill, and of solids to fall down-hill, has ended in the finer material working down towards the lower levels, leaving only the stones and gravel at the top. Indeed, the whole of the "soil-cap" has a tendency to work bodily downwards, and thus we see the headland at the bottom hedge of a field accumulating up against the fence, while the top headland shrinks away from the same, thus in time producing a difference of level between the surfaces of two adjacent fields on the same slope.

Peat Mosses.—There is one special form of soil, or at least of soil material, which does not come under any of the above descriptions—that of peat moss. Peat moss is wholly a vegetable growth, or rather the residue of vegetation which has accumulated under certain conditions. These conditions are a cool moist climate and the presence of stagnant water. Stagnant water is of course mostly found in hollows, and therefore mosses are found mostly there, though sometimes on high lying or sloping ground also, as on the side of the Pentlands, where it grows faster than it can be washed down when it is left alone by man. In such places aquatic plants such as *Sphagnum*, *Hypnum*, *Polytrichum*,* &c., grow, die, and decay. The decay is, however, early arrested by the presence of the stagnant water in which is formed humic, ulmic, geic, and other acids, and by the absence of oxygen, as decay of organic material is largely a matter of oxidation of the more or less complex organic compounds through the agency of microbe life. This goes on continuously until the hollow becomes filled up, or so long as the water is prevented from draining away, and is held by the spongy nature of the peat as formed. Peat moss in its natural state is not, of course, a soil, and the surface requires to be artificially manipulated to form one; first draining to take out the water, then burning off the surface rubbish, liming, cultivating, and so on, eventually resulting in a soil very similar to that naturally occurring on the prairie, but soft and yielding, and cool and moist below. Where peat is absolutely left alone it continues to grow, even in our days when the rainfall must be less than in byegone ages when the country was all forest; but it seldom is left alone, draining at least being resorted to as the primary work of "improving" the same.

Summary.—We have now seen that there are a great many agencies all at work in the making of soils: the oxidizing power of the

---

* Geikie (J.): "Geology," p. 113.

atmosphere; the dissolving, eroding, and washing power of water; the solvent power of water containing carbonic acid gas and other acids; the splitting power of ice and of growing roots; the development of humus or organic matter; the working of earth worms; and so on: all of which have been in force for many thousands of years and are at work now, still further weathering, modifying, and remaking them.

When the British Islands first rose up out of the azure main they were composed of a series of humps of barren, bare rock, upon which all those agencies mentioned immediately began to work and make soil of some sort on each of the various kinds of rocks or formations. The intervention of the "Great Ice Age" put an end to the making of these primeval "earths" in some districts, and this was not resumed until the disappearance of the glaciers some 7,000 or 8,000 years ago*—the effect of these being momentous on all northern regions as regards the soil and the forming of the same.

Of all the changes and modifications worked on the face of the earth by means of the disintegrating agencies which made the soil, and the various deposits of the countless strata, the greatest amount has been done by water. "Not only does water possess the advantage of being triple armed for the accomplishment of its work, exerting its force as vapour, liquid, or solid, but it is capable, under varying circumstances, of either chemical or mechanical action. Thus through all the ages of geological activity it is to water more than to all other agents combined that the physical and chemical features of the earth have been due: rock formation and rock disintegration being alike the result of its action; mountain and valley, rock and soil, being but varying records of its perpetual activity and all-reaching power." †

The processes described above in the formation of a soil by no means come to an end when that soil is made, or has come to that state when it is fit to grow a crop, but continue to act, making and remaking the material over and over again, or carrying the formation to a greater degree of perfection. Indeed, in a natural unstirred soil they "slow down" as it were, and for the artificial purposes of cultivation do not keep the soil material in an active or ready-made state sufficiently suitable for the needs of cultivated—that is, artificial—plants. To remedy this, cultivation or tillage is necessary,

* Dawson: "Salient Points in the Science of the Earth," p. 476.
† Stockbridge: "Rocks and Soils," p. 96.

and all the ordinary acts of husbandry performed on or in the soil—such as draining, liming, tillage, and even manuring—are in one sense only a continuation of the natural processes by which the soil was produced out of the original rocks,* carried further by artificial means to assist the growth of artificial plants.

Notwithstanding the large number of complex agencies which are at work, the manufacture of soil from the disintegration of rock is a very slow process. Liebig calculated that it required 12,000 years to make one inch of soil. This may be the rate of disintegration of some of the harder rocks, but it cannot be the typical or average case. Ramsay has shown that from 9,000 to 11,000 feet of solid rock has been stripped off large parts of Wales,† and at the above rate it would require an unthinkable length of time to do this, while the Thames Valley has been already shown to be lowered by disintegration at the rate of one foot in 1,000 years. The author would like to point out that, assuming that it is correct to suppose that the Glacial Epoch wound up about 8,000 years ago, and that soils in general are plough-deep, then the soils on the glaciated areas, of the British Islands at least, will average one inch per 1,000 years as the rate of formation.

---

* Storer: "Agricultural Chemistry," Vol. I., p. 126.

† Darwin: "Vegetable Mould and Earthworms," p. 231.

CHAPTER III.

MINERALOGY OF SOILS.

Rocks in general are very complex bodies, being made up of separate and separable components which are in themselves very complex. These rock-forming bodies are called *Minerals*, and a mineral in the pure state is a definite chemical compound with a definite chemical formula, and which can occur naturally (or in some cases artificially) in the form of a regular-shaped crystal. By far the greatest proportion of these rock-forming minerals are either silicates, carbonates, or sulphates,* and their number is almost legion—something like about 600 having been examined and described by mineralogists,† while the number is being gradually added to; but the vast majority are little more than scientific curiosities, of rare occurrence and of little practical concern to mankind. There are indeed only about ten minerals which form the mass of the earth's crust—*i.e.*, all the solid rock and loose material forming the 57 miles of crystalline and igneous rock and three miles of sedimentary strata which compose the solid part of the earth—and the following are their relative proportions‡ :—

1. Felspar	48	per cent.
2. Quartz	35	"
3. Mica	8	"
4. Talc	5	"
5. Carbonates of lime and magnesia ...	1	"
6. Amphibole (hornblende) ...		
7. Pyroxene (augite)	1	"
8. Diallage		
9. Peridot (olivine)...		
10. Clay (in all its forms)	1	"
11. Other substances	1	"
	100	

The "other substances" of most importance in agricultural

* Dana: "Manual of Geology," p. 52.
† Prestwich: "Geology," Vol. I., p. 25.
‡ Ibid., p. 26.

science are the oxides of iron, carbonate of iron, iron pyrites, sulphate and phosphates of lime, and common salt. Of course there are many more mineral substances in the world of vast importance to farmers in an economic and manurial sense, such as nitrate of soda, sulphate of ammonia, kainite, &c., but they do not occur in sufficient quantity to form an appreciable percentage, while as mineral economics of special importance to agriculture they will be mentioned again later on. Furthermore, as our concern is here especially with soils it is only those of most importance in the formation of the same that more particularly interest us.

In order to thoroughly understand the formation of soils, and the nature of the materials out of which they have been made, it is necessary to study, up to a certain extent, the composition and characteristics of those minerals which compose the principal rocks, because this formation has literally been due to the weathering or other decomposition of the same.

The inorganic part of every soil has been most largely made from some or other of these above-named ten minerals, and while the fragments and stones in the soil are pieces of rock or mineral in its original form, it must be noted that a large proportion of the soil—all the "earthy" part—is composed of "alteration products"—that is, the weathered and decomposed parts of the same—and it is the province of this branch of mineralogy to trace out these and the bearing they have on the composition and formation of a given soil. The proportion of "earth," or loose incoherent material which forms part of all soils, is an important point in the study of the same, and some typical examples may here be given* :—

	Earth.
Loamy clay soil	97 per cent.
Alluvial soil from clay slate	92 „
Do. from mica slate	84 „
Granular marly alluvium from gneiss ...	80–70 „
Weathered mica slate, and soils from hard schistose rocks	70–60 „
Alluvium from clay slate and weathered gneiss soil	60–50 „
Red sandstone soil	50–40 „
Granite soil	40–30 „
Heath sandy soil	30–20 „

* Ansted: "Applications of Geology, &c.," p. 15.

In investigations of this kind we are, however, met at once with a great difficulty. When examining a rock in mass, or a hand specimen, it is comparatively easy to say what it is, and of what minerals it is composed, either right off from appearance, or after suitable investigation; but in examining a soil where the fragments are minute, or partly or wholly decomposed material, it is very difficult to identify the same. Further, mere identification is not enough, because the farming qualities of a soil depend, not only on the kinds of bodies present, but also on the relative proportions of the same. Now in ordinary technical mineralogy, while we can say that in the case of a piece of granite, for instance, there are three definite minerals present, and can point out the separate crystals of each, yet it is a very difficult operation—and at best yielding only approximate results—to separate out these minerals, and tell the *percentage* proportion of each present. This being so difficult in a definite straightforward case like granite, it may be realised how it is next to impossible to do so in a complicated mixture like the soil. An attempt has been made to do this by triturating the material in certain solutions of known specific gravity, in which minerals with corresponding specific gravities will float. For example, the specific gravities of some of the leading minerals are as follows :—

Gypsum ...	2·20—2·40	Augite ...	2·88—3·50
Orthoclase ...	2·53—2·58	Tourmaline	2·94—3·24
Albite ...	2·62—2·67	Amphibole ...	2·90—3·30
Oligoclase ...	2·63—2·68	Fluor spar ...	3·10—3·20
Quartz ...	2·65	Rutile ...	4·20—4·30
Calc. spar ...	2·65—2·80	Heavy spar...	4·30—4·70
Anorthite ...	2·67—2·76	Pyrites ...	4·90—5·20
Black mica ...	2·74—3·13	Magnetic iron ore ...	4·90—5·20
Muscovite ...	2·76—3·10		

Thoulet and Goldsmidt use a solution of iodide of mercury and iodide of potassium in water, giving various specific gravities according to the relative proportions used, and can thus "float off" the minerals with corresponding gravities. For example, 210 grammes of potassium iodide, 280 grammes of mercury iodide, and 25 c.c. of distilled water produce a solution of 3·196 sp. gr., on which fluor spar (3·1 to 3·2) will float, as will the others lower in the scale of gravities* and in this way some little progress has

* Wahnschaffe: "Scientific Examination of Soils," p. 95.

been made towards arriving at a knowledge of the mineral composition of soils—but not much.

The study of the soil from a mineralogical point of view, however—*i.e.*, the separation, identification, and estimation of its components in the same way as we enquire into the structure and composition of a rock containing several compound minerals—is the true key to unlock stores of knowledge on the nature and differences of the same. Unfortunately little of this knowledge exists ready to hand, for two reasons : first, because of the greater difficulty of investigating soils in the usual mineralogical manner, with blowpipe, microscope, polariscope, spectroscope, goniometer, dichroscope, and all the others ; and secondly, because the study of anything pertaining to agriculture was until lately entirely beneath the notice of the great men of learning, with a few noble exceptions. A few years ago, for instance, the dons of a great university, met in congregation, treated with laughter and scorn the proposal to teach agricultural science within their sacred precincts, and the undergraduates' organ of the same institution followed suit with jeers and scorn, set off with Latin and Greek quotations. Now the same great university gives degrees in agriculture under the superintendence and teaching of a special set of professors, readers, lecturers, &c. Another great university has had a chair of rural economy for many years, but the teaching has hitherto been confined solely to the subject of agricultural chemistry, and agriculture itself has been ignored.

Now that the capabilities and usefulness of this branch of knowledge are being more recognised at the seats of learning, we may hope to see some progress made, and the author respectfully submits that the mineralogy of soils—the study of the lithology of the same and collation to the parent rocks—is a quarry which would well repay working, and out of which huge blocks of knowledge might be dug, of practical value to the farmer and landowner.

It has long been known that an ordinary chemical analysis of a soil is of comparatively little value—may, indeed, be misleading—and we may now see some of the reasons for this. The visible "proximate constituents," while coming under such heads as "sand," "clay," "limestone," &c., are largely made up of minute and, no doubt, partly decomposed mineral or rock fragments, but these have great variations in their chemical composition, in their solubility, and generally in their fitness as a storehouse for the

food of plants. On the other hand, an ordinary chemical analysis merely gives the total of each kind of element, or the ordinary oxide of the same, as so much silica, alumina, lime, potash, phosphoric acid, and so on, without stating how these are combined. A case in point bearing on this may be given with regard to phosphoric acid. This body, of course, never exists in the soil as an acid alone, but always combined to form a phosphate. If lime is the base, then it is all right, because the three or four phosphates of lime all become, eventually, more or less useful to plants, if not immediately; but if, on the other hand, it is combined with alumina (Wavellite) or iron (Vivianite), then it is more or less worthless and ineffective. Again, in the case of potash, if this is locked up in felspar or some other mineral, it is obvious that it is not so readily available as if present as sulphate or, possibly, nitrate. Thus it is that soils which from their analyses would appear to have plenty of a certain ingredient present often respond to an application of the same as a manure, showing that the quantity naturally present must be combined in some insoluble mineral, requiring an attempt at a mineralogical examination to explain the value or otherwise of the same.

As already pointed out, in the present state of science an exact mineralogical analysis of a soil cannot be made, so that no more can be done than merely to point out that investigation in future must largely follow on those lines. We can, however, to some extent examine any given rock, the weathered "alteration products" derived from the same, and the soil made from the latter; and we may justly infer that the composition of the last depends largely on the composition of the first, and thus derive valuable hints as to the character of the latter in regard to manuring and cultivation. A few examples will best illustrate this, and thus bring us from the general to the particular. The Carse of Gowrie is a clay soil derived from the disintegration of the slates, schists, &c., of the Silurian region of the Highlands to the north-west. The minerals of these are rich in potash—such as felspar and mica, not to mention those of the gneiss and granite formation of the area drained by the Tay—and therefore the said Carse soil is also rich in potash (over 2 per cent. by analysis) and needs no potassic manures. The Cheviots are largely formed of igneous rocks of the felspathic-trap type * which are rich in everything of importance to

* Geikie (A.): "Outlines of Geology of British Islands," p. 103.

plants, and consequently—though they are too high and rugged for cultivation—the soil is so good that they are green with grass to the tops. The Stonesfield Flag is a formation occupying a very limited area in England, yet as it is particularly rich in phosphates the out-crop of the same is marked by a strip of extreme fertility, where clover naturally grows as well as if the land had had a heavy dose of basic slag. The mountain limestone is the basis of hills which are celebrated as sheep runs from the short sweet pasturage in which sheep's fescue (*Festuca ovina*) is a feature, and, indeed, several breeds of sheep in the north of England—such as the Limestone, Lonk, and Penistone breeds—are special to the same, as will be detailed later on. Such examples could be multiplied infinitely, but these will show that a knowledge of the nature of the underlying rock, or at any rate of the source whence the materials of a given soil have been derived, is often, indeed nearly always, a guide to the nature of the soil, and the manuring and other management of the same.

As above stated it has long been known that the chemical analysis of a soil carried out in the ordinary way is of very little use, or only of use in certain cases, while it may actually be misleading in many respects. In the analogous study of rocks the "chemical analysis of aggregates of minute and undetermined minerals serves only to throw a very imperfect light upon the precise nature of the component minerals themselves, and in this way rocks which widely differ in minute structure and in mineral composition often yield almost identical results so far as their ultimate chemical composition is concerned"*; so in the study of soils an analysis which takes no notice of the particular minerals, decomposition products, and other chemical compounds—soluble, difficultly soluble, and insoluble—is very partial and incomplete, and may not only fail to give a farmer the information he particularly desires, but prevent him hunting it up in other directions by putting him on the wrong trail.

It is the opinion of some that much more might have been done in working out the geology and mineralogy of soils than has actually been accomplished. The following quotations from an American writer puts it very clearly:—

"It would appear from the intimate relation between the mode of formation and the fertility of soils that, when the geologic

---

* Rutley: "Study of Rocks," p. 2.

origin and general character of any soil is determined, its productiveness might be formulated—that the geologist, especially if also a chemist, ought to be able to predicate the agricultural value of a soil just as he estimates the mineral value of a rock formation. Actually, however, his determinations in the former field have not the practical value that theoretic considerations imply. . . . .

"It must be confessed that the geologist is compelled to rely mainly upon just such observations as does the practical farmer in his primary determinations of the productiveness of soils. . . .

"The agriculturist observes that a soil of given character yields certain returns under given conditions of tillage; and hence, instinctively it may be, infers that every similar soil will yield like returns under identical conditions. . . . .

"In like manner, the practical geologist learns the absolute productiveness of a soil from empiric observation alone; *but in extending his enquiry to other soils and into other lands he not only possesses every advantage known to the agriculturist, but many more besides;* for he is principally concerned with the minor features that quite escape the attention of the untrained observer: the character of the materials of the deposit, whether clay, marl, sand, gravel, boulders, or a mixture of several of these; the chemical composition of the whole, as well as of its constituent materials; the fineness or coarseness, the hardness or softness, the compactness or porosity, the tenacity or friability, the homogeneity or heterogeneity of the mass; the structure, vertical range, horizontal extent, and stratigraphic relations of the formation—all these and many more factors in the fertility and economical value of the soil are carefully scrutinized and correlated in all possible combinations. Moreover, he is necessarily familiar from personal observation with a wide range of soils, and is, in addition, conversant with the work of other geologists in precisely similar lines of investigation in nearly every land on the globe. Again, the researches of the thorough geologist extend into meteorology, terrestrial physics, and related branches of knowledge; and he is hence cognizant not only of the facts of rain-fall, precipitation of dew, winds, frost, mean temperature, annual and diurnal thermometric range, &c., but of their results as affecting the surface of the earth, the waters, and vegetal and animal life. But these are not all of his advantages: his theoretic classifications and speculative conclusions, which are so frequently regarded with contempt if not with the absolute abhorrence which heterodox opinions have ever encountered, enable

him to presage in a general way the agricultural value of unexplored regions; to readily identify all deposits, however rare, and approximately evaluate their soils; to roughly classify the lands of a State from two or three trips across it; and to systematically and accurately determine the relative value of all the soils of any area with less than a tithe of the labour required by the purely empiric method."*

Although we have, up till the present, scant information on the subject, yet there is some in existence which it is desirable to lay before the reader, while an outline of the whole science of Mineralogy, so far as it applies to soils and the farming of them, will form a basis from which a start can be made and an indication given of the lines of future investigation.

It is customary in studying the composition of soils to consider that they are made up of certain "proximate constituents," and that the endless variations in the texture, wetness, dryness, and all the other physical characteristics of soils are due to relative proportions of these same. It will be shown later on that this does not meet the case of the endless variations due to the lithological character of the material out of which the soils have been made, but as it forms a handy mode of classification, and is a basis for further study, it is here now set out.

These proximate constituents are as follows:—

Sand.	Humus.
Clay.	Gravel or stones.
Carbonate of lime.	

These names are almost self-explanatory, or, at any rate, so much has incidentally been said about them above, or will be below, that it is unnecessary to follow the lead of some text-books and give a treatise on each, and therefore no special description of them, or explanation regarding them, need now be gone into. Soils are named in accordance with the preponderance of one or more of these constituents. Schübler founded his famous classification upon them nearly 60 years ago,† but the minute subdivisions and exact percentages he gave are looked upon as foolish now. The similar seven kinds or classes of soils tabulated by Albrecht Thaer

* McGee: "Geology and Agriculture," pp. 5–8. *Iowa State Hort. Soc.*, 1884.

† Schübler: "Agricultural Chemistry"; also Wrightson: "Handbook of Agriculture," p. 46.

are, and probably will continue to be, standard names for all soils, both in scientific and practical use.* These seven are tabulated as follows :—

Stony.	Clayey.	Limey.
Sandy.	Marly.	Humous.
Loamy.		

These practically include all possible types of soils as far as their physical or visible characteristics go—any given soil which does not come under one or other of these must be an intermediate form or a combination of two or more of the same.

Having now given this preliminary information and limitation, we may next proceed to study more closely the nature of the minerals and the rocks composed of the same ; the débris of which forms the bulk of all our soils, and the occurrence of which determines the physical characteristics of a country side.

It is desirable to begin with the minerals, and these are now taken up *seriatim*, and the character of each detailed. It is very difficult to arrive at any satisfactory system of classification of these from an agricultural point of view. No two writers of text-books on mineralogy adopt the same system, and none the present writer has seen is other than misleading as far as a study of soils and farming are concerned. The least objectionable is that of grouping them according to their principal components—the system adopted here ; but it is also desirable to know which are "secondary" or "decomposition products," the result of weathering or other action, and these are indicated by italics. Some of the primary minerals, however, occur as secondary products in many cases, so that any attempt at classification is exceedingly difficult whichever way is adopted. In the following list it will be noticed that in some cases the same mineral occurs in more than one class according to circumstances.

List of the Principal Soil-Forming Minerals.

I. Silica—

Quartz.	Nepheline.	*Kaolinite.*
Felspar.	Leucite.	*Chlorite.*
Mica.	Epidote.	*Pinite.*
Amphiboles.	Schorl.	*Glauconite.*
Pyroxenes.	*Talc.*	*Zeolites.*
Olivine.	*Serpentine.*	

* Wahnschaffe : "Scientific Examination of Soils," p. 21.

II. LIME—		
Calcite.	*Phosporite.*	*Gypsum.*
Apatite.		
III. MAGNESIA—		
Magnesite.		
IV. SODA—		
Halite.	*Nitratite.*	
V. POTASH—		
Glauconite.	*Nitre.*	*Sylvine.*
Pinite.	*Kainite.*	
VI. CARBON—		
Carbonates.	Humus.	
VII. IRON—		
Pyrite.	*Limonite.*	*Delessite.*
Magnetite.	*Siderite.*	*Vivianite.*
Hæmatite.		
VIII. PHOSPHOROUS—		
Apatite.	*Vivianite.*	*Wavellite.*
Phosphorite.		

QUARTZ.—Quartz is oxide of silicon ($Si\ O_2$) or silica, and is represented in many forms in nature. In its purest form it appears as transparent hexagonal prisms, samples of which are to be found chiefly in museums, as there are not many found out in the country. Another museum form is *Chalcedony*, appearing in botryoidal masses of a bluish opaque colour. In the form of *Flint* stones or gravel and common siliceous sand, however, it is very plentifully met with in practical farming as one of the principal components of a soil—occurring, indeed, in the soil and in the parent rock with exactly the same chemical composition—there being nothing of the nature of an "alteration product" in the case of this material; its mechanical or physical condition only being altered by the action of ice, water, or other agents. *Jasper* is practically flint coloured red (or brown or yellow) with oxides of iron.

Ordinary sand is composed of exceedingly small quartz pebbles —as seen under the microscope—more or less translucent, and coloured with some iron oxide adhering to the surface of the grains, and but seldom entering into the composition of the same. They

have for the most part been waterworn in some former state—as we see in the case of the grains which compose sandstone or freestone—and thus are rounded off before they become ingredients of the soil; but in many cases the silica occurs as "flour" in the clay of soils—*i.e.*, in exceedingly fine particles, just as it was set free from the weathering of a rock, like granite or trap.* (Plate I.)

FELSPAR.—Chemically, felspar is an anhydrous silicate of alumina, with potash, soda, and lime. The three varieties are named Orthoclase felspar (potash), Albite felspar (soda), and Anorthite felspar (lime). Potash felspar is the principal ingredient of granite, while the felspars generally occur in large quantities in many of the other igneous rocks. Their composition is very variable, as the alkaline bases can and do partly replace one another. They all readily weather down under the action of the ordinary disintegrating agencies, though albite is the least easily affected in this manner; while the fertility of the resulting soil will be much influenced by the class of felspar which predominates,† potash felspar (Orthoclase) being the best.

Various forms of kaolin, clay, and marl are derived from the direct weathering of felspars, as explained above (p. 38), while the various colours and compositions of varieties of this are due to "impurities" such as iron compounds, carbonaceous matter, &c.

Felspars are really double or even triple silicates of alumina with the alkalies and alkaline earths, while, of course, in nature the actual composition of the clay which results from the weathering of felspar varies considerably according to the mixture of materials there is to begin with and the amount of decomposition that has taken place. The average of some samples of naturally pure kaolin (hydrated silicate of alumina) is as follows:—

Silica	46·4	per cent.
Alumina	39·7	„
Water...	13·9	„
	100·0	

$=Al_2O_3 + SiO_2 + 2H_2O$; while the composition of some actual varieties of clay was tabulated above (p. 40).

Soils which contain some undecomposed felspar have a nearly

* Wahnschaffe: "Scientific Examination of Soils," p. 83.

† Johnstone: "Agricultural Chemistry and Geology," 17th Ed., p. 126.

inexhaustible reserve of mineral plant food, which gradually becomes available as decomposition progresses.*

MICA is a double silicate of alumina combined with one or other of the following: potash, magnesia, lime, iron, lithium, or fluorine. It occurs as thin shining elastic and transparent plates in such rocks as granite, mica-slate, &c. Mica-sand is composed of this ground down to small fragments, and many samples of ordinary sand or sandy soils contain a notable proportion of it in the shape of small shining scales of a pearly or sub-metallic lustre. The principal variety of mica is Muscovite—white or potash mica. Biotite—a silicate of alumina with magnesia, potash, or iron—is another more complicated variety, the colour of which is usually black or dark green. Mica weathers down very slowly—as shown by its existence as shining scales in various sands, sandstones, and soils—but owing to its fissile structure it assists very much the breaking up of any rock of which it is an ingredient. For some reason not understood, the rocks containing white mica (as the granites) are more friable and more easily disintegrated than those containing Biotite.†

AMPHIBOLES.—Silicates of lime, alumina, magnesia, iron, and manganese, which occur in basaltic rocks of a greenish or brownish colour, and are represented by many varieties, such as hornblende, actinolite, tremolite, jade, and asbestos. Hornblende weathers into chlorite with formations of calcite and quartz, and these—like augite—yield a mixture of carbonates, limonite, clay, and quartz.‡

PYROXENES.—The principal members of this group are Augite (aluminous) and Diallage (non-aluminous). They are essentially composed of silicates of lime, magnesia, and iron, with or without alumina; but no potash or soda. They are hard and tough, and weather down very slowly, but yield fertile débris from the amount of lime, magnesia, and iron oxide contained. They are essential components of basalt, diabase, and other igneous rocks. Trap rocks are augitic, and therefore the soils from the same are fertile. The normal weathering of augite leads first to the formation of chlorite, then further weathering destroys this and yields a mixture of carbonates, limonite, clay, and quartz,§ the very materials wanted for a soil. Not infrequently there are

* Wahnschaffe: "Scientific Examination of Soils," p. 95.
† Merrill: "Rock Weathering, &c.," p. 24.
‡ Rosenbusch: "Physiography, &c.," p. 251.
§ Ibid., p. 241.

considerable quantities of phosphoric acid present, this further improving the quality of the resultant débris.*

OLIVINE (Chrysolite, Peridote).—A silicate of iron and magnesia. An essential ingredient of basalt, dunite, lherzolite, and pickrite, and prominent in many lavas, diabases, gabbros, and other igneous rocks.† This changes readily and extensively into serpentine along the lines of fracture, until sometimes huge masses are altered into this latter mineral. The change from a chemical point of view is very simple: about 13 per cent. of water is absorbed, and a proportion of the magnesia is separated out as a carbonate. Silica may sometimes be separated out from the displacement by carbonic acid.

NEPHELINE.—A silicate of alumina, soda, and potash. Occurs mostly in tertiary and post-tertiary eruptive rocks (lava), and also in phonolite, tephrite, and nephelinite.

It undergoes a ready alteration, giving rise to zeolitic minerals, and on ultimate decomposition on weathering yields a rich and fertile soil.‡

LEUCITE.—A silicate of alumina with a high percentage (21·5) of potash. Occurs in recent lavas, but is not an abundant rock constituent. It is inferred that it must yield a large proportion of potash to the soils formed from the same. It is a common constituent of certain Vesuvian lavas, and probably some of the excessive fertility of the lava soils of that neighbourhood, and their suitability for vine growing, is due to the decomposition of this mineral setting free large quantities of potash §; potash being an essential and most important ingredient in grape (and all fruit) growing.‖

EPIDOTE.—A silicate of alumina with iron and lime. This is one of the minerals which give the characteristic colour to the "greenstones" of the older nomenclature (altered basalts, diabases, diorites, gabbros, &c.),¶ and though it occurs as a "primary" mineral in many granites, gneisses, and schists, it is more common as a secondary or alteration product resulting from the weathering

* Stockbridge: "Rocks and Soils," p 63.
† Merrill: "Rock Weathering. &c.," p. 24.
‡ Ibid., p. 19.
§ Ibid., p. 18.
‖ Ville: "Artificial Manures," p. 396.
¶ Merrill: "Rock Weathering, &c.," p. 25.

of felspar, pyroxene, amphibole, and mica. It is the most common silicate in the weathered débris of these bodies.*

TALC.—A silicate of magnesia occurring in foliated and flexible non-elastic plates, greasy to the touch, of a white, grey, or green colour, and more or less translucent. Steatite or soapstone ("French chalk") is a massive amorphous variety. Talcose rocks weather down with extreme difficulty and form little or no soil.†

SERPENTINE.—A hydrous silicate of magnesia. The prevailing colour of the same is green, and the mineral in mass is soft enough to be cut with a knife. It is an alteration product derived typically from olivine rocks, but also from some others which contain magnesia as a principal ingredient. It seems to be almost wholly unaffected by atmospheric weathering agency, and wherever it forms the surface there is no soil or vegetation.‡

KAOLINITE.—Chemically is pure china clay, a hydrated silicate of alumina, and the basis of all our clay soils. Kaolinite occurs in exceedingly small six-sided crystalline plates, with a few rhomboidal ones,§ recognisable under the microscope, and as thin as the 1-40,000th of an inch in thickness. Usually it exists as amorphous material—"kaolin"—mixed with no end of "impurities" forming soils or the different kinds of clay beds, and coloured with iron oxides or organic matter. Clay which burns red in brickmaking contains the hæmatite form—red anhydrous sesquioxide.||

CHLORITE.—A hydrous silicate of magnesia, alumina, and iron protoxide, of which the predominating colour is a yellowish green. It is a common ingredient of eruptive rocks, schists, slates, and marls. It is usually looked on as a secondary product from the decomposition of pyroxene, hornblende, or mica, and gives the colour to many of the "greenstones." Ripidolite and Viridite are varieties.

PINITE.—A secondary or decomposition product resulting from the breaking down of felspar, nepheline, &c. It is a hydrous silicate of alumina, iron, and potash, of which the latter is the predominating ingredient; occurs in some granites, and is related

* Rosenbusch: "Physiography, &c.," p. 271.
† Stockbridge: "Rocks and Soils," p. 117.
‡ Ibid., p. 117.
§ Dick: "On Kaolinite," p. 16. *Mineralogical Magazine*, 1888.
|| Dana: "Mineralogy," p. 333.

to serpentine. It is believed to be the form in which potash exists in some potash-rich soils.*

GLAUCONITE.—A variable compound consisting of a silicate of iron and potash, with other bodies—as alumina, lime, magnesia, and soda—present. It is always a secondary mineral, formed from the breaking down of siliceous crystalline rocks, and of a green colour, as, indeed, it is the mineral which gives the characteristic colour to the "greensand" formations of all kinds. (Plate I.)

SCHORL.—This is the black form of tourmaline, and occurs mostly in some forms of granite at Luxullian in Cornwall. It is the special ingredient to which is attributed the infertility of these soils in that neighbourhood.† It is a silicate of alumina with a certain proportion of *boric acid* present, together with variable proportions of iron, manganese, potash, soda, or lithia.

ZEOLITES.—This group of minerals, generally speaking, consists of hydrous silicates of alumina with varying percentages of lime, potash, soda, and barium, but *no magnesia or iron;* while they contain a large percentage of water—over 20 per cent. in at least one case (Chabazite). They may be colourless, white, grey, or reddish, and are easily dissolved by the weaker acids. They are wholly secondary products resulting from the decomposition of other minerals. Their special interest in this book lies in the fact that there is much evidence to prove that they occur in soils as regular constituents thereof in a state of minute subdivision, though we cannot isolate and examine them directly, even with the help of a microscope ‡; and, indeed, that the "soluble" ingredients of the same—*i.e.*, the material immediately available as plant food—exist in the form of some or other of these zeolites. Further, it is believed that the addition of manurial material to the soil—more especially the artificial chemical varieties—produces zeolitic compounds as the first result of coming into contact with the soil ingredients. Dyer found that a one per cent. solution of citric acid dissolves out of the soil as much material as the roots of the plants can directly utilise, and we are at liberty to infer that it is zeolitic material which is thus acted on most readily.

At the same time we must not lose sight of the fact that the existence of zeolites in the soil is not yet proved to the satisfaction

* Merrill: "Rock Weathering, &c.," p. 376.
† De la Beche: *R. A. S. E. Journal*, 1842, p 33.
‡ Johnson: "How Crops Feed," p. 330.

of every one. Merrill maintains, for instance, that the potash exists in the decomposition products of felspar, nepheline, scapolite, &c., to which the name *Pinite* is given, and mentions the case of the potash-rich soils of Maryland to prove this, while it may also exist in glauconite forms.* Zeolites are almost entirely absent from the secondary, unmetamorphosed rocks which are formed out of the same débris as soils, while soils themselves are only the leached residue of rock débris, so that from this point of view the inference is that zeolites do not exists in soils, and at this we must leave it pending further investigation.

A very large number of zeolites have been examined, analysed, and classified, and the following table gives a list of the most important :—

TABLE OF ZEOLITES.

Name.	SiO_2	Al_2O_3	CaO	K_2O	Na_2O	H_2O	Chemical Formulæ.
Ptilolite... ...	70·0	11·9	4·4	2·4	0·8	10·5	$(Ca \cdot K_2 \cdot Na_2)\ Al_2 \cdot Si_{10}\ O_{24} + 5\ H_2O$
Merdenite ...	67·2	11·4	2·1	3·5	2·3	13·5	$(Ca \cdot K_2 \cdot Na_2)\ Al_2 \cdot Si_{10}\ O_{24} + 7\ H_2O$
Heulandite ...	59·2	16·8	9·2	—	—	14·8	$Al_2O_3 \cdot 3\ SiO_2 + CaO \cdot 3\ SiO_2 + 5\ H_2O$
Stilbite	57·4	16·3	7·7	—	1·4	17·2	$Al_2O_3 \cdot 3\ SiO_2 + CaO \cdot 3\ SiO_2 + 6\ H_2O$
Pectolite ...	55·6	1·4	32·8	—	8·9	2·9	$4(CaO \cdot SiO_2) + Na_2O \cdot SiO_2 + H_2O$
Leonhardite...	55·0	22·3	10·6	—	—	11·9	$Al_2O_3 \cdot 3\ SiO_2 + CaO \cdot SiO_2 + 3\ H_2O$
Analcime ...	54·5	23·2	—	—	14·1	8·2	$Al_2O_3 \cdot SiO_2 + Na_2O \cdot SiO_2 + 2H_2O$
Apophyllite ..	58·7	—	25·0	5·2	—	16·1	$4(CaO \cdot 2\ SiO_2) + KF + 4\ H_2O$
Laumonite ...	51·9	21·1	11·7	—	—	15·0	$Al_2O_3 \cdot 3\ SiO_2 + CaO \cdot SiO_2 + 4\ H_2O$
Phillipsite ...	48·8	20·7	7·6	6·4	—	16·5	$(Ca \cdot K_2 \cdot Na_2)\ Al_2 \cdot Si_4\ O_{12}$
Natrolite ...	47·4	26·8	—	—	16·3	9·5	$Al_2O_3 \cdot 2\ SiO_2 + Na_2O \cdot SiO_2 + 2\ H_2O$
Chabazite ...	47·2	20·0	5·5	—	6·1	21·2	$Al_2O_3 \cdot SiO_2 + CaO \cdot SiO_2 + K_2O \cdot SiO_2 + Na_2O \cdot SiO_2 + 7\ H_2O$
Harmotome ...	47·1	16·0	—	2·1	$\left\{ \begin{matrix} BaO \\ 20·6 \end{matrix} \right\}$	14·1	$A_2O_3 \cdot 3\ SiO_2 + BaO \cdot 2\ SiO_2 + 5\ H_2O$
Scolecite ...	45·8	25·5	13·9	0·3	0·2	14·2	$Al_2O_3 \cdot 3\ SiO_2 + CaO \cdot SiO_2 + 3\ H_2O$
Prehnite ...	43·7	24·8	27·1	—	—	4.4	$Al_2O_3 \cdot SiO_2 + 2(CaO \cdot SiO_2) + H_2O$
Thomsonite ...	36·9	31·4	11·5	—	6·4	13·8	$(K \cdot Na_2)\ Al_4 \cdot Si_4\ O_{16} + 5\ H_2O$

Being comparatively soluble and decomposable, there is a constant series of changes and interchanges in their composition as they exist in the soil, due to such agencies as the presence of varying amounts of moisture, applications of lime, dung, or artificial manures, the action of cultivation in mixing the particles of soil anew and exposing fresh surfaces to the atmosphere, and so on.

* Merrill: "Rock Weathering, &c.," p. 376.

The different alkaline bases can partly replace one another in this double-silicate form, and the usual order of replacement, according to Way, is as follows:—soda, potash, lime, ammonia.* There is, however, no invariable order and no complete replacements, and all depends on which particular compounds come into contact with one another in the soil, the amount of these, and various other factors as just noted above. Ammonia, although a "volatile alkali," has the greatest affinity for uniting with soil compounds,† and the absorption of it from the air must be in a manner analogous to the formation of a zeolite. Chabazite, by way of example, yields lime if digested with solution of any alkali or alkaline earth; and other minerals act in a similar way, but the following bodies do not seem to have any decomposing power on sulphates, nitrates, or zeolites existing in the soil:—

Quartz sand.
Kaolinite.
Calcium carbonate.
Humus.
Hyd. oxide of iron.
Hyd. alumina.
Humates of lime, magnesia, and alumina.
Phosphate of alumina.
Gelatinous silica.
Do. air-dried.

The first six of these have no absorptive power at all—together or separately.‡

Water containing carbonic acid gas has a great solvent power on zeolites, so that in damp soil they are likely to be largely in a a state of solution mixed through a large bulk of soil; while the "pan" which forms in bog-land contains a proportion of these hydrated silicates along with the iron compounds.§ Their usual "decomposition product" in this case is a clay with carbonates of the corresponding alkalies.

Zeolites are estimated to exist in the soil to the extent of 4 to 5 per cent.||

CALCITE (Carbonate of Lime).—In the crystalline form it occurs in cavities in many rocks as calcite, but in the amorphous and

* Johnson: "How Crops Feed," p. 344

† Tanner: "Elements of Agricultural Chemistry," p. 115.

‡ Johnson: "How Crops Feed," p. 348.

§ Ibid., p. 352.

|| Tanner: "Elements of Agricultural Chemistry," p. 145.

massive form it is found as not only the principal, but almost the only component of marble, oolite, chalk, and limestone rocks of various kinds, while in marl and many varieties of calcareous sandstone (building) it is the principal ingredient. The pure calcite has the composition $Ca\ CO_3$, but as a rule all varieties of limestone are more or less impure, and coloured by iron and organic matter. Some limestones are highly siliceous, the calcareous matter having been accompanied by silica in the act of deposition; others are argillaceous, sandy, ferruginous, dolomitic, or bituminous. Limestone may weather down into calcareous sand from the fact that the crumbling effect of freezing water acts more quickly than does the weathering of the atmosphere, but ultimately the solving effect of water containing carbon dioxide reduces the carbonate completely.

APATITE.—The mineral form of tribasic phosphate of lime, with a little fluoride of calcium, occurring in microscopic quantities in almost all eruptive rocks; but in granulated limestones, schists, and others, occurs in massive forms of sufficient importance to be valuable as a mineral phosphate for use as a fertilizer. It is the only common rock constituent containing phosphorous, and is important on this account. In the impure amorphous form it is known as *Phosphorite*. As the tribasic form of phosphate is the usual form in which phosphoric acid occurs in soils, and as all kinds of phosphatic manures applied to the soil eventually have their phosphates assuming the tribasic form either from union with alumina, iron, or more lime, we may assume that much of the phosphate in the soil is in the condition of an amorphous form of apatite. The *Phosphorite* of Estremadura; the black *Phosphorite* of North Wales*; the *Coprolites* of the Crag and Greensand formations; *Charleston Phosphate;* and the tricalcic phosphate of guanos, bones, and all other phosphatic manures, are simply various forms chemically identical with that in apatite. Pyrophosphorite occurs in guano, and also the hydrated calcium phosphates known as Brushite and Metabrushite.†

GYPSUM.—This is mainly a chemical deposit occurring among stratified rocks, resulting from the evaporation of water of inland seas or lakes, or from a variety of chemical actions and decompositions. It is a hydrated sulphate of lime, and often occurs naturally in massive form or beds in the Trias group, generally in

* Davies: "The Phosphorite Deposits of North Wales."
† Dana: "Mineralogy," 6th Ed., p. 234.

conjunction with magnesian limestones. It is sometimes used *per se* as a top-dressing for meadows, while in America it is largely used as a disinfectant in cowsheds—or rather for the purpose of soaking up the liquid manure—under the name of "land-plaster." It is the ultimate form of lime resulting from the oxidation of gas-lime, largely used for dressing land; so that, in one form or another, it is to be met with in most agricultural soils.*

MAGNESITE (Carbonate of Magnesia).—The principal constituent of magnesian limestones, where it occurs up to as high a proportion to the other carbonate as three to one. The pure anhydrous form is called *Magnesite*, and has the symbol $Mg\,CO_3$. It weathers readily. Normal *Dolomite*—the crystalline form—is composed of about equal molecular proportions of the two forms in combination ($Mg\,CO_3 + Ca\,CO_3$), while a large proportion of the massive form of the Magnesian Limestone formation is formed of granular dolomite.

HALITE (Common salt, or Chloride of Sodium).—This is a pretty widely-distributed mineral, either in the form of beds of rock salt, or as an ingredient of sea-water or of the water of salt lakes. It is also a common ingredient of soils, forming, indeed, a large proportion of the "soluble salts" contained therein, and which can be extracted by lixiviation and evaporation of the filtrate.

NITRATINE (Nitrate of Soda).—From its manurial importance this substance must be here noticed in our list of minerals. It only exists in soils where a dressing of the same has been put on as a manure, and probably only for a short time, until it is dissolved by the rain and has soaked into the soil and become assimilated. Nitrogen is absorbed by the roots of plants in the form of nitric acid combined in some kind of nitrate, and this particular nitrate is the most convenient commercial form for practical use as a nitrogenous manure. It is exceedingly deliquescent and soluble; will absorb moisture readily from the air; and is easily leached out of soils by the ordinary rainfall; so that it is thus best applied during the growing season, and in small quantities at a time, repeating the same if necessary.

Nitrate of soda has a peculiar mechanical effect on clay soils when first applied; it seems to have the reverse action of lime, and causes a sort of puddling of the clay in contra-distinction to the coagulating action of lime. Some 18 years ago the author had his attention called to this by his men, who affirmed that a wheat field

* Stockbridge: "Rocks and Soils," p. 65.

which had had some nitrate of soda .applied to it, and was afterwards ploughed up (from failure of the plant), was much more stiff for the horses to pull the plough through than in the case of the undressed soil. The sand or rock-flour in the clayey soil showed up after rain on the places so dressed, while the soil below was more sodden than it ought to have been. This probably happens, more or less, in all soils, but is not usually noticed because nitrate is generally put on a growing crop after cultivation has ceased for the time, and also because it is usual to put it on in conjunction with some phosphatic manure—such as "slag" or "mineral phosphate"—and the lime in these counteracts this action.

NITRE, SALTPETRE (Nitrate of Potash).—This occurs as an ingredient of rich soils in the warmer parts of the world—such as in China, India, Peru, and Chili—but it has been found in the soils of Rothamsted, though only to the extent of a few parts per million. On the sites of old villages in Egypt, India, and elsewhere, the "nitre-earth" has been found to be valuable enough to use as a manure by the natives; while the "nitre-beds"—where manure, old plaster, wood ashes, &c., were allowed to ferment to develop nitric acid from the action of microbe life—are a familiar example of the occurrence of this product.

It is, of course, too expensive to use as a manure, owing to its value for gunpowder manufacture, but it most probably occurs in soils recently dressed with stable manure, while it forms wherever there is an accumulation of refuse animal and vegetable matter protected from rain-wash.

KAINITE.—Of the many forms of potash salts occurring in the German mines this is the most important.

It has a very complex composition, as will be seen from the annexed analysis :—

Water	3·4
Water of combination	10·9
Potash sulphate	24·4
Soda chloride ("salt")	30·4
Magnesia chloride	14·3
Magnesia sulphate	13·2
Lime sulphate	2·7
Silica	·7
	100·0

Of these, the sulphate of potash is the most important, and it is as a potash manure that this salt is chiefly used.

Another form of potash manure is the chloride or muriate (*Sylvine*), generally guaranteed by manure merchants to contain 80 per cent. of the pure salt. It is usually, however, considered harmful to apply this variety to root crops—sugar-beets especially, as the sugar produced will not crystallize—though it gives often good results with corn, grass, &c. On the whole, Kainite is the favourite ingredient to add to soils as a potash manure.

CARBON.—In its pure crystalline form as the diamond it is, of course, never met with in connection with soils or farming—excepting, perhaps, in the ring on the finger of a "gentleman farmer," a species now almost extinct—but in the form of peat, the humous matter of soils, and the carbonaceous matter generally contained in many rock formations it is one of the most important bodies in the whole range of this department of enquiry.

It is often only recognisable as the colouring matter of other mineral bodies. "The carbonaceous flakes are without regular boundary, opaque, lustreless, and grey to greyish black by incident light."*

In the gaseous form as carbon dioxide ($C O_2$) it is, when dissolved in water, one of the most common solvents in the weathering of rocks—partly by the formation of carbonates—while many of the soluble minerals in the soil are in the form of carbonate salts.

PYRITE.—The crystalline form of Disulphide of Iron. In this form it occurs in many slates and also in coal, but it often forms a large proportion of many subsoils, and may, indeed, be the cause of the barrenness of some. It is directly poisonous to plants, and even the sulphate, or green vitriol, which results from its oxidation, is also injurious if present in a large quantity. Even as little as ·5 per cent. of this sulphate in the soil renders it almost barren, and on land containing more than one per cent. nothing whatever will grow.† Ordinary cultivation and exposure to the air, combined with liming, will improve such a soil, but it may take a time.

It is principally on account of the presence of this mineral in subsoils in an amorphous form, or the sulphate resulting from the same, that subsoiling as an operation on the land has to be under-

* Rosenbusch: "Physiography, &c.," p. 123.

† *R. A. S. E Journal*, 1865, p. 115.

taken with care. The subsoil must be brought up and mixed with the soil proper in small quantities only, and time given for the oxidation and leaching of the same, otherwise the operation will do harm to the soil. Many fields have been injured for years owing to too much of the sulphide or sulphite being brought within reach of the roots by subsoil ploughing, *i.e.*, bringing up the bottom to the top in contradistinction to stirring only with a cultivator.

Experiments have shown that a small quantity of ferrous sulphate ($Fe\,S\,O_4$) added to the soil or to a heap of manure preserves the ammonia. It would appear, however, that this is due really to its poisonous qualities; it kills the germs which cause the decaying processes, as any other antiseptic would do, and thus prevents or retards the changes necessary to the formation and evolution of ammonia.

MAGNETITE (Magnetic Iron Ore).—Its composition is iron protoxide *plus* iron sesquioxide.

It occurs as an almost universal constituent of eruptive rocks, but in such small quantities as to be quite inconspicuous. Under the effects of the weather it decomposes slowly and yields hydrated sesquioxide, which colours the clays and sands and soils formed from its matrix, but is not of any other value.

HÆMATITE (Anhydrous Sesquioxide of Iron).—When this occurs in large beds it forms the valuable ore known as "specular iron ore," but in the amorphous condition it forms the cementing constituent of many red sandstones, and is the colouring material of both rocks and soils where bright red predominates. It adheres to the outside of the grains of sand only—as seen under the microscope—as the inside of the grains are found to be of a different colour when washed with acid.* (Plate I.)

GŒTHITE (Hydrous Peroxide of Iron).—Intermediate between the last and the next forms of iron oxides. It gives the yellowish colour to soils and formations.

LIMONITE (Brown Iron Ore, or Hydrous Sesquioxide of Iron).—This is one of the most widely distributed compounds of iron, as apart from its existence as a colouring material it occurs as a valuable iron ore—"bog iron ore" being the common variety.

It is a secondary body resulting from the decomposition of various compounds of iron—silicate, sulphide, sulphate, carbonate, and anhydrous oxide, as met with in the forms of glauconite,

* Green: "Physical Geology," p. 199.

pyrite, copperas, siderite, &c., all of which decompose in damp air. To it is most largely due the brown colour of soils, though this may vary from yellow to red according to the amount of oxidation and hydration present.

TURGITE is practically a variety of this, forming the red ochre or "Keil" used by shepherds for marking sheep.

Limonite occurs in the amorphous form, mixed up with the particles of soil and adhering to the surface of these as a brown stain or entering into their actual composition. It is to the presence of this or its less hydrated forms that many soils—especially those of the various red sandstones—owe a large amount of their good qualities, as already explained.

The pure mineral contains about 60 per cent. of metallic iron, while the ore and impure forms sometimes contain humic acid.* It occurs in largest quantities in the soil of low-lying or swampy ground, often impregnating and enveloping fragments of wood, leaves, mosses, &c., and forming an ochrey deposit in drains and ditches.

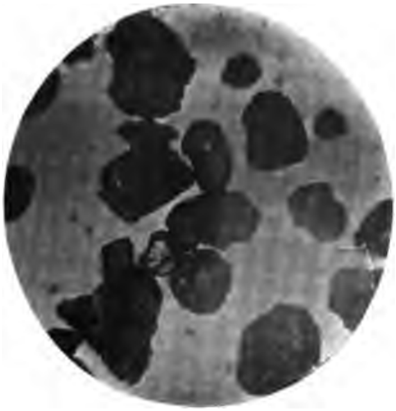
SIDERITE (Carbonate of Iron).—The particular interest in this from a farming point of view lies in its being often an ingredient of boggy or low-lying soils. In its massive form it occurs as the clay ironstone and blackband ironstone from which much of the iron of commerce is smelted, but on some farms it is an unmitigated nuisance from its liability to choke up drains and ditches. The scum which forms on some ditch water from action of microbe life, and which becomes deposited as a soft brown ochrey material in the drain pipes and watercourses of some farms, is simply a flaky impure form of this mineral, and is often a source of great trouble and expense in keeping the same cleared away.

DELESSITE.—"Green earth" owes its colour to the presence of this decomposition mineral. It is usually looked on as merely a stage in the decomposition of augite, and is most largely met in connection with decomposing trap rocks. It has sometimes been called "ferruginous chlorite" as it is allied to this latter mineral.†

VIVIANITE (Hydrated Phosphate of Iron).—In all soils the phosphoric acid combines with some base to form a phosphate, the most desirable base being lime. But it does so with other bases, iron among the number, and this yields a compound chemically

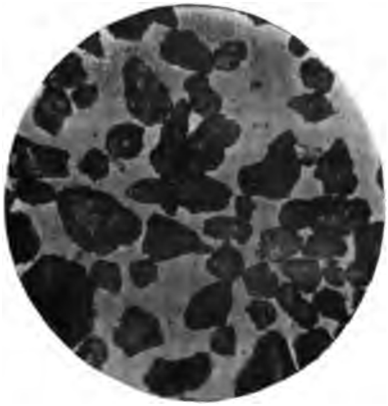
* Bauerman: "Descriptive Mineralogy," p. 128.
† Dana: "Mineralogy," p. 497.

PLATE I.

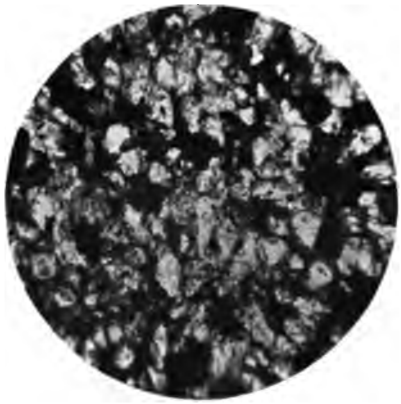


Crystalline Sand: Permian: Penrith.

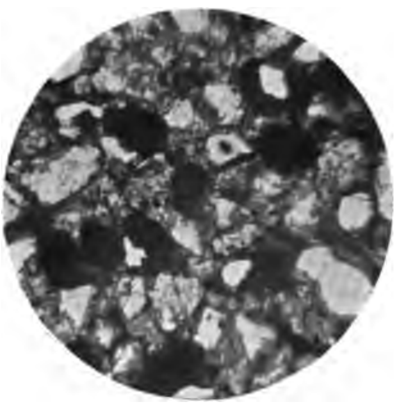
Crystalline Sand, cleaned with Acid: Permian: Penrith.



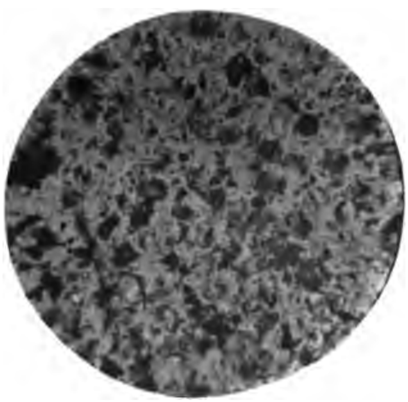
Angular Sand: Lower Greensand: Surrey.



Siliceous Sandstone: Carboniferous: Yorkshire



Glauconitic Sandstone: Upper Greensand: Surrey.



Arable Loamy Soil: London Clay: Essex.

identical with the above mineral. The crystalline form is rare, but the amorphous form—blue iron earth—is quite common, even in soils, or rather in subsoils. By actual experiment phosphate of iron is of no manurial value for crops as compared with the different forms of phosphate of lime, and superphosphates with much iron in them are undesirable because of the tendency of the "soluble" phosphate in the same "reverting" to this ferruginous compound, so that mineral phosphates in use for the manufacture of superphosphate must have as little iron in their composition as possible.

Vivianite is often found in proximity to decaying animal or vegetable matter, also in some peat mosses forming a blue crust on the dried peats, while its presence in the soil is a matter of inference.*

WAVELLITE (Hydrous Phosphate of Alumina).—It is sometimes found as a massive stony cream-coloured rock in the West Indies, but it is inferred to exist in the amorphous condition in soils—at least after an application of dissolved phosphatic manures, as this is one of the forms to which phosphatic manures "revert" in common with the preceding body.

ROCKS.

THE MOST IMPORTANT VARIETIES.

Having seen what is the nature and composition of the principal rock-forming minerals we may now consider the nature of the rocks themselves. While the composition of a mineral is fixed and definite, and can even be represented by a chemical formula, that of a rock is indefinite and mixed, so that petrologists are not agreed as to the exact numbers of these, owing to the difficulty of defining a rock "species." The numbers are variously estimated at between 200 and 300†; fortunately only about 50 of these are of any importance as the source of soil-forming material.

Owing to this variation of opinions among petrologists as to what constitutes a definite species of rock, or which are to be reckoned definite types or varieties, the classification of the same is in a chaotic condition; no two authorities, indeed, agreeing in this matter, but each putting out his own system. In order to be in

* *R. A. S. E. Journal*, 1856, p. 470.
† Prestwich: "Geology," Vol. I., p. 25.

the fashion the author has followed this plan, and evolved a classification of his own, largely founded, however, on that of Prestwich.* It is necessary to do this, moreover, for several reasons: first, because there are only some 50 kinds of rocks of any importance as yielding material to form soils, or as in some way or another influencing the face of the country and the farming of the same; while again, some 200 are left out of account altogether, although many of them are of the first importance to the ordinary mineralogist or metallurgist; and lastly, because some of secondary importance to these investigators are of prime importance to those who, like the author, live their life in the country. A classified list of varieties of importance in the present investigation, drawn up to show which they are and how they stand related to their neighbours, was necessary, and it is here now given. The whole is divided into three groups—*Igneous*, *Sedimentary*, and the intermediate *Metamorphic* forms. All the different strata or formations are composed more or less of some of these now given; it will here be sufficient to point out what are the prevailing minerals in each and its mode of occurrence, and leave the description of the corresponding soils and farming to the chapter on the *Formations* themselves.

List of Principal Soil-Forming Rocks.

A. IGNEOUS.

I. Plutonic—

Granite.	Felsite.
Syenite.	Diorite.
Porphyrite.	Diabase.

II. Volcanic—

Dolerite.	Trachyte.
Leucite-lava.	Phonolite.
Basalt.	Volcanic Ash.
Trap.	

B. METAMORPHIC.

I. Massive—

Granite.	Serpentine.
Syenite	Dolomite.

II. Schistose—

Gneiss.	Clayslate.
Mica-schist.	

* "Geology," Vol. I., p. 26, *et seq.*

C. SEDIMENTARY.

I. ARGILLACEOUS—

Clay.	Shale.
Loam.	Marl.

II. CALCAREOUS—

Common Limestones.	Oolite.
Magnesian Limestone.	Chalk.

III. SILICEOUS—

Sandstones—	Grauwacke.
1. Siliceous.	Breccia.
2. Calcareous.	Conglomerates.
3. Felspathic.	Loess.
4. Argillaceous.	Alluvium.
5. Flaggy.	Sand.
6. Marly (Molasse).	Gravel.
7. Gritty.	Shingle.
8. Greensand.	Flint.
9. Gaize	
10. Ferruginous (Carstone).	
11. Mudstone.	

IV. CARBONACEOUS—

Peat.

A.—IGNEOUS.

I.—PLUTONIC.

GRANITE.—As its name implies, this is a crystalline granular rock (from the Latin, *granum*, a grain), typically consisting of an admixture of at least three minerals—quartz, mica, and orthoclase felspar—in distinct crystals. (Plate II.) The mica is usually black or dark coloured (biotite), but it may be grey, yellow, green, or even white. The felspar may be opaque-white, red, or grey, and the quartz transparent or white. There are many varieties of granite, the variations depending principally on the particular kind of mica or felspar which is present, and some of the more important ones must be mentioned. The common forms of "grey" (Aberdeen and Dartmoor) and "red" (Peterhead) differ mostly

in the colour only. The "porphyritic" granite met with at Lamorna (Cornwall) and Shap (Cumberland) differs from the others in having the felspar in huge distinct crystals—sometimes as large as the open hand. The variety called *Syenite* is devoid of quartz, and sometimes has the mica replaced by hornblende—so that it is simply a compound of felspar and hornblende, as met with in Skye, Leicestershire, the Malverns, and the Channel Islands. The syenite of Syene, in Upper Egypt, from whence the name is derived, and from which the monuments of ancient Egypt were made, is a red hornblendic granite.

Sometimes the mica is replaced by black tourmaline (schorl) where it is in contact with other rocks, and is called "schorlaceous granite" or Luxullianite—from Luxullian, in Cornwall, where the inferior fertility of some land there is, as already mentioned, traced to the presence of this mineral in the granite of the district.* Granite with the grains so small as to resemble sandstone is known as "granulite," as met with on Dartmoor, in which case the mica is generally absent.

Granite in weathering generally first decomposes into its component minerals, accompanied by a more or less important production of clay; this clay being "gritty" from the undecomposed mineral grains or quartz flour contained in it.

As the silica is practically undecomposable, and the mica slowly so, the weathering of granite is very largely a question of the decomposition of the felspar.

The weathering of granite, as of other rocks, however, is very much a question of weather. In Egypt the ancient monuments, from 3,000 to 5,000 years old, preserve the same polish on their surfaces as when freshly made, while in other places the rock *in situ* is wholly demoralised to the depth of many feet from atmospheric action alone. Thus in Aberdeenshire (Ellon), in Cornwall, and in the Channel Islands, the decomposed granite can be dug with a spade as easily as any gravelly soil.

PORPHYRY, or Porphyrite, is practically wholly composed of felspar, as it is an amorphous felspathic base (red or green) full of light coloured crystals of oligoclase (lime) felspar, as met with in the Pentland Hills. The altered earthy product of this is known as "claystone."† The soil formed is generally rich in lime as well as potash, though of a stiff clay character.

* De la Beche: *R. A. S. E. Journal*, 1842, p. 33.

† Prestwich: "Geology," Vol. I., p. 40.

QUARTZ-PORPHYRY (Elvanite).—Composed of much the same as the above with quartz in addition. Forms the "elvans" or dykes of Cornwall.

FELSITE (Felstone, Hälleflinta, Eurite, or Petrosilex) is an intimate mixture of felspar and silica forming a compact rock of opaque colour (grey, red, green). It weathers with a bleached surface, and is very common among the Silurian rocks of Wales and Cumberland.

DIORITE.—One of the "greenstones" of the older mineralogists, so called from the prevailing colour. It is a granular compound—the grains often quite distinct—of oligoclase felspar and dark green hornblende, often passing into an amorphous, fine-grained, compact rock. It is generally greenish-grey or greenish-black in colour, the coarser varieties having a speckled or blotched appearance. It occurs mostly as dykes or intrusive sheets, and sometimes in weathering shows the spheroidal concentric formation of mass structure. Typical examples are found at Cader Idris, Wales, and St. Mewan, Cornwall. It weathers slowly, but yields a fertile loam free from quartz grains.

DIABASE.—A granular mixture of orthoclase felspar and augite with some chlorite.* The colour is usually dark green, this being another of the "greenstones." It usually becomes permeated along the fissures and interstitially with viridite, this being a decomposition product of the augite. Common in Scotland, Cumberland, and Dolgelly.

II. VOLCANIC.

DOLERITE.—A black or dark grey fine-grained compound of augite and labradorite, with some titaniferous iron. It is generally so intimate a mixture that the component parts cannot be distinguished. Prestwich includes the ordinary lava of volcanoes under this name,† and if this classification is right, then this rock does not occur in the British Islands, as volcanic rocks proper are held not to exist here. On the other hand we have always been used to reckoning one variety of igneous rock as of this kind, so that the author prefers to retain the name. (Plate II.)

* As an alteration product according to Rutley: "Study of Rocks," p. 245.
† "Geology," Vol. I., p. 36.

LEUCITE-LAVA (Amphigenite).—A compound of augite and leucite—or at least part of the labradorite replaced by leucite. This is one of the typical lavas of Vesuvius, and is interesting from the point of view of this enquiry from the fact that the excellency of the soil of many of the vineyards of the neighbourhood of that volcano is traced to the decomposition of the lava containing this particular mineral leucite as noticed above; not met with, of course, in the British Islands. In St. Michael's, one of the Azores, the natives pound up this volcanic material and use it as a dressing for the cultivated land, as it speedily yields a rich soil; while in ascending the slope of Vesuvius this lava can be seen in all stages from that of recent flow to its thorough disintegration into soil.*

BASALT.—This and dolerite are often indistinguishable from one another, the difference being not in their composition but in other characteristics. Basalt is more massive, blacker, often in columnar formation, with a more or less conchoidal fracture, while sometimes it contains crystals of olivine. Typical examples are, of course, the Giants' Causeway; Fingal's Cave, Staffa; Samson's Ribs, Edinburgh; and the "Whin Sill" generally of the North of England. It occurs in streams, sheets, dykes, and necks. It weathers very slowly, yielding a brownish marly product containing much oxide of iron.

TRAP.—This is in a general way basalts or greenstones of which the successive streams have flowed in great horizontal sheets, and in weathering given rise to a steplike structure of the formation in the mass. It is in fact an augitic lava of greater age than the lavas of modern volcanoes or eruptions. Trap soils are always more or less fertile from the large proportion of lime, magnesia, and oxides of iron contained in the same from the weathering of the augite (or sometimes from hornblende) in the original rock; felspar (the other principal mineral ingredient) being rich in potash. As the augite weathers very slowly the country remains rugged and precipitous, but forming good pasturage for sheep walks. Hundreds of square miles in the Lowlands of Scotland, the North of Ireland, Cornwall, and elsewhere, have their soils vastly improved from the amount of trappean material incorporated with the same.† When the soil is wholly of trappean origin it has been found—as in many cases in the Lothians, in Fifeshire, and in Ayrshire—that when

* Stockbridge: "Rocks and Soils," p. 75.

† Johnstone: "Elements, &c.," 17th Ed., p. 129.

first broken up it was deficient in lime, and a dressing of the same did much good, but no subsequent dressing had any effect. The explanation is that trap débris is rich in lime, but that the top soil had had it all leached out; the subsequent cultivation, however, brought up fresh undecomposed particles which gradually yielded a supply, thus rendering a second artificial dressing superfluous.*

TRACHYTE.—A variety of volcanic rock which takes its name from the rough (τρᾱχὺς) feeling it has to the touch. It is very complex in structure, being formed of a mixture of sanidine † with oligoclase, hornblende or augite, quartz, and mica (biotite), and thus has many varieties.

PHONOLITE.—Called "Clinkstone" in the country from the fact that it emits a ringing sound (φωνή) when struck with the hammer. It is a dark-greenish or brownish felspathic rock, of varying composition, and breaking up into slaty or tabular masses. Yields a whitish marl when weathered, of an unmanageable and sterile nature in dry districts, but fruitful where there is sufficient moisture. Its principal components are sanidine and nepheline, with some hornblende and magnetite. Some zeolites are often developed in the mass of this rock, such as natrolite, stilbite, thomsonite, chabasite, analcime, apophyllite, &c., resulting from the decomposition of the nepheline.

Phonolite generally occurs in the form of conical masses or hills, sometimes showing columnar structure, and having a tendency to split into slabs or slates sufficiently fine for roofing purposes in some localities. In advanced stages of weathering it becomes of an earthy consistency known as phonolite-wackè.

VOLCANIC ASH.—The name given to beds which have been formed of material discharged into the air from volcanic vents in the form of ashes and cinders. They are generally interstratified with sedimentary strata, and solidified. The material in its first form consisted of dust, ashes, sand, lapilli, and even volcanic bombs; while lithologically it consists of small fragments of lavas, crystals of felspars, augite, olivine, biotite, magnetite, &c. (Plate II.), and owing to this complexity of composition the soil which results from the weathering of the same is always fertile. Good examples are the "ash beds" of the Lake District, Brent Tor in Devonshire, and some deposits in the Silurian strata of Wales.

* Johnstone: "Elements, &c.," 17th Ed., p. 120.

† A glassy variety of orthoclase felspar.

B. METAMORPHIC.

I. Massive.

Serpentine.—A hydrated silicate of magnesia which occurs as a dark green, mottled red and black rock, of a greasy touch, and sometimes soft enough to be cut and carved with a knife. It frequently contains crystals of diallage, and is often traversed with white veins of steatite. It is generally impure from admixture with silicate of iron ($Fe\,Si\,O_3$), sesquioxide of chromium, argillaceous matter, and carbonates of lime and magnesia. It may be formed as the result of the metamorphosis of several different rocks, but especially from the decomposition of rocks rich in olivine.

The typical samples of this rock are to be met with at the Lizard in Cornwall—where it forms a barren track with some peculiarities among its flora which will be noticed later on,—at Balhamie Hill, and Lendalfoot in Ayrshire,* Portsoy in Banffshire, and Westport in Wicklow; while a calcareous form called ophiocalcite is found among the Cambrian rocks of Anglesea, and it forms the "green marble" of Connemara.

Dolomite.—The crystalline form in a pure state of magnesian limestone, which occurs often as a constituent of rocks and also in the massive form. In the latter case it is a light-coloured rock which weathers very slowly, but which forms the basis of the physical features of the country of a peculiar character in some places on the continent, as in the case of the Dolomite Mountains of the Tyrol. In this country, however, there are many examples of "dolomitized limestones" among the carboniferous limestones of Kilkenny and Cork. As it does not materially differ from magnesian limestone the soil resulting from the weathering of dolomite is somewhat the same.

II. Schistose.

Gneiss.—A rock which consists of the same minerals as granite in variable proportions, but with these minerals (quartz, mica, and felspar) in a foliated arrangement instead of being irregularly mixed. Indeed, the two rocks differ only in the arrangement of their ingredients, though, of course, as regards origin, the gneiss is regarded as a metamorphosed sedimentary rock. The rock is schistose, or even fissile, on account of the thin distinct bands of mica through it.

* Bonney: "On the Serpentine, &c., of the Ayrshire Coast."

Mica-schist.—An aggregate of mica and quartz of a fissile or foliated nature, enabling the rock to be easily split up. It is of common occurrence among the "Archæan schists" of the Highlands, and indeed is the most common and widely distributed of all the varieties of schistose rocks.* The foliated condition of the rock allows of the ready infiltration of water, and while weathering from chemical action is very slow, there is a certain amount of physical degradation resulting eventually in the formation of micaceous sand. (Plate II.)

Clay Slate.—The commonest form of this is ordinary roofing slate of various kinds, of a dark blue, purple, or greenish colour, compact and fine-grained. It consists of an argillaceous base, sometimes containing mica or talc in an extremely fine state of division, while crystals of iron pyrites are also often abundantly present. It must have originally been deposited as mud or clay, and afterwards developed the well-known cleavage from metamorphism, at various angles to the line of bedding. The principal varieties in the British Islands are of Cambrian and Lower Silurian age, though many varieties of rock of a slaty nature are met with of more recent origin abroad. When it weathers it produces material very similar to that from which it was made—a muddy clay, impregnated with particles of mica, quartz, chlorite, &c.

C.—SEDIMENTARY.

I. Argillaceous.

Clay.—A soft hydrated silica of alumina, with more or less free silica, and insoluble in acids. Becomes plastic when moist with water, and hardens when subjected to the action of fire, which drives off the waters of combination. When containing diffused oxide or sulphide of iron, or organic carbonaceous matter, it is of a dark or bluish grey colour, but often varieties occur of a red, purple, yellow, or green colour, from the presence of either the peroxide or protoxide of iron. Calcareous clays may contain segregated masses of impure limestone called septaria. When free from sand

* Merrill: "Rock Weathering, &c.," p. 169.

they are usually of fine texture. Clay has originally been deposited as mud, in most cases at the bottom of the sea or in estuaries, though sometimes there are local deposits over the land due to deposition from floods, lakes, or ice action. The principal typical deposits of clay are the Boulder Clay or Till, London Clay, Oxford Clay, Kimmeridge Clay, Weald Clay, &c., while, of course, all the stiffer soils have a large proportion of it in their composition.

LOAM.—According to the usual acceptatión of the term as applied to soils it is an admixture of clay and sand. If the mixture consisted of equal parts it would be too stiff and adhesive for easy cultivation, and would, in country phrase, be reckoned a stiff clay soil; so that, in this case, a loam must have a large proportion of sand in it. The "loam" of the brickmaker, on the other hand, must have a larger proportion of clay with a smaller proportion of *fine* sand present. According to Donaldson* a good loam contains 87 per cent. of sand and 13 per cent. of clay, while a standard clay soil contains 70 per cent. of sand and 30 per cent. of clay. The word "loam" signifies a fat, unctuous, tenacious soil, and is, perhaps, the best representative in a general way of ordinary "earth"; while, of course, there may be all grades of the same according as either the sand or the clay predominate in any given sample. (Plate I.)

SHALE.—Clay or marl hardened and laminated in the plane of original deposition. The lamination is generally aided by the presence of mica, sand, or carbonaceous matter, as met with in the shales of the Coal Measures.

MARL (Calcareous Clay).—Clay with more than four per cent. of carbonate of lime in its composition, but which generally retains its plastic nature: if indurated it becomes "marlstone," which, however, falls to pieces on exposure to the weather. The chalk-marl and the marlstone of the Lias are typical examples, but in many deposits of clay—such as the London Clay, the Red Marl of the Trias, and Chalky Boulder Clay of East Anglia—there are beds and strains of material which are valuable either as actual soils or for supplying material as a top dressing to the land.

* "Clay Lands and Loamy Soils," p. 106.

II. Calcareous.

Limestone.—Pure Limestone consists of carbonate of lime, but it generally contains a certain amount of "impurities," such as clay, sand, or colouring due to oxide of iron or organic matter. It occurs in the massive form as the Mountain Limestone, Silurian Limestones, Devonian Limestones, Chalk-rock, &c., while hydraulic and siliceous limestones are special varieties. This rock has a decided effect in influencing the soil, farming, and general features and characteristics of the country where it occurs, either in the mountain or massive form, in layers, or as a soil ingredient.

Pure limestone would be white, but it is seldom met with in this state outside the chalk formation, as it is generally coloured with some ingredient.

The various varieties of limestone rock are most valuable from an economic and farming point of view, as the source of lime for dressing land, for mortar-making purposes, and as building stones; while as the basis of the soil they yield the best pasture in a district, though often too rocky for arable purposes.

Magnesian Limestone.—As lime and magnesia are isomorphous, there is no definite ratio between the proportion of the two carbonates in the combination, so that a magnesian limestone may contain from mere traces of the magnesian carbonate up to three times as much of this as of the calcic carbonate.

A true dolomite has equal molecular proportions, which gives the $CaCO_3=54{\cdot}35$ per cent. and $MgCO_3=45{\cdot}65$ per cent. by weight. The dolomite is reckoned a metamorphic rock because it shows traces of crystallization, but it is the ordinary magnesian limestone which is of most importance in this enquiry. Magnesian Limestone is one of the specific formations of the Permian group, having special physiographical features of its own, which will be noticed in the proper place; while beds of this also occur in the carboniferous limestone series of Derbyshire and elsewhere.* Indeed, examples are not wanting of cases where ordinary limestone has become dolomitized subsequent to its deposition in beds with enclosed fossils. How this has been caused cannot be satisfactorily explained,† though it is conceivable that it is due to infiltration of water saturated with salts of magnesia.

Oolite.—The special form of limestone of the oolite formation,

* Rutley: "Study of Rocks," p. 285.

† Prestwich: "Geology," Vol. I., p. 114.

in which the calcareous material occurs in the form of rounded grains from the size of peas (Pisolite) downwards, embedded in a matrix of the same material. (Plate II.) The rocks are generally of a light yellow colour, cut freely and easily as we see in the Bath stone and Portland stone for building purposes, and yield a thin light loamy soil.

Chalk.—A nearly pure form of carbonate of lime, forming a soft white rock, sufficiently soft to soil the fingers, but often containing large proportions of alumina and silica. The chalk of Kent and Sussex—forming the North and South Downs—and of Salisbury Plain are typical examples. The chalk is in some cases, but not always,* composed of the shells or tests of species of foraminifera (Plate II.), but in weathering the calcareous part is wholly dissolved by percolating water charged with carbonic acid gas, and only the "impurities" left behind. The soil is thus often a typical brown loam utterly devoid of calcareous material, while it tends to a clay in some places. There are, of course, cases in which the present "regolith" of the chalk is not formed from material *in situ*, but from that which has been transported from a distance; but in general it occurs as the residue of the chalk dissolved on the spot.

III. Siliceous.

Sandstone consists of rounded grains of quartz cemented together with various kinds of matrices—siliceous, clayey, calcareous, ferruginous—and forming free working stone. Mica and felspar are often quite common, while the colour is due to the same cause as in other rocks, such as clays, iron in various stages of oxidation, or carbonaceous matter. There are many varieties of sandstone of which the following are the principal:—

1. *Siliceous.*—Grains of sand consolidated with a cement of silica and a little clay; soft, friable, and permeable to water, but passing into impermeable quartzite. The sandstones of the Coal Measures, New Red, &c., are examples. (Plate I.)

2. *Calcareous.*—Compact sandstones in which the sand grains are very fine, and cemented together by carbonate of lime. The Kentish Ragstone is one of the best examples of this rock, but it is largely developed in the Nummulitic rocks of Central Europe.

* Rutley: "Study of Rocks," p. 288.

3. *Felspathic.*—Common in the Millstone Grit and Permian strata and wherever there is granite in the neighbourhood. Sandstone with some grains of felspar interspersed and partly decomposed.

4. *Argillaceous.*—Sandstones in which the grains are mixed with a proportion of clay, and often coloured with iron oxides. Where the clay is in large proportion, rocks of this nature will weather down rapidly and form clayey débris. Many of the red sandstone beds of the Coal Measures and of the New Red Sandstones are formed of this rock, and when a section is exposed it will be noticed that beds of this material weather away more rapidly than the hard sandstone does.

5. *Flagstones.*—Hard sandstones rich in mica, which split easily along the planes of deposition. They are common in many of the formations in different forms, of which the Yorkshire and Caithness Flagstones are examples.

6. *Marly Sandstone.*—A form of calcareous sandstone, micaceous, and greyish in colour. If the marl is in large proportion the rock is soft and friable. The minerals composing this rock being rich in the ingredients of plant food, the soil formed from this is usually very fertile. This rock forms the "Molasse" of Continental geologists, and Rissler has much to say regarding the same from a soil and farm point of view.* The Continental forms are of Miocene age, and it is doubtful if this rock occurs in Britain at all.

7. *Grit.*—Coarse or pebbly sandstone such as forms the Millstone Grit. Sandstones of this sort are generally very deficient in the elements of fertility; the size of the particles indicating that little useful material would accompany them in deposition, while any small amount would be washed out afterwards from percolation on account of the loose open texture of the stone.

8. *Greensand.*—Some of the strata of the Upper Greensand consist of sandstone beds containing dark green grains of glauconite in sufficient quantity to colour the same and give rise to a distinctive variety. (Plate I.) This weathers to a rusty brown colour and the soil is generally one of the most fertile of the lighter class from the iron and potash of the glauconite.

9. *Gaize.*—An important constituent of some strata occurring in the form of a very light porous rock of a calcareous sandstone nature, and met with in the Upper Cretaceous series. Its special

* Rissler: "Geologie Agricole," III., Chap. XV.

characteristic is the presence of a large proportion of silica in the form of an impalpable white powder, which is soluble in weak acids. There has been found 24 per cent. in the Upper Gault, 46 per cent. in the Firestone, and 72 per cent. in some beds of the Upper Greensand of this soluble silica, and there is reason to believe that the flints found in the chalk have been formed by a precipitation of some of this soluble material round polyzoa, corals, sponges, &c. It is one of the sources of fertility in the soils of the Greensand, and by itself forms a soil of great fertility in some districts in the Ardennes and the Meuse in France.*

10. *Ferruginous.*—A sandstone with a cement consisting of the hydrated peroxide of iron, which in weathering takes on a yellow or brown colour. A special example of this is the dark brown "Carstone" of Norfolk, Cambridge, and Lincolnshire.

11. *Mudstone.*—A soft fine-grained argillaceous sandstone, sometimes with so much clay present that it weathers down exceedingly easily, forming a *muddy* soil. It is rather common among the Ludlow and Wenlock strata.

Grauwacké.—A variety of rock consisting of grains of sand cemented with slaty matter, micaceous or calcareous, sometimes forming a hard argillaceous grit. The name, rather an old-fashioned one, is confined to some of the partly metamorphosed rocks of the older formations, and, indeed, this variety of rock might be included in the metamorphic group, though as varieties of it are found in the Silurian system it is looked on as sedimentary in origin.

Breccia.—Angular fragments of siliceous material imbedded in a compact argillaceous, calcareous, siliceous, or ferruginous cementing material. Sandstone, quartz, jasper, and various eruptive rocks are common in their composition, while they even occasionally consist of fragments of limestone. From the angular nature of the fragments it is inferred that the material cannot have travelled far, and is, indeed, most likely to have been derived from the superficial disintegration of the rocks in the immediate vicinity, as in a talus or rubbish heap cemented together by infiltration of various kinds. The principal breccias are of Permian age; indeed the "necks" of this formation—*i.e.*, old volcanic vents—are generally filled up with a breccia formed of ejectamenta known as "Volcanic Agglomerate."

* Prestwich: "Geology," Vol. II., p. 284.

CONGLOMERATES.—This differs from the last in that the imbedded fragments are water-worn, it being, indeed, a deposit of gravel or shingle cemented into a hard rock. If our gravel beaches or deposits were to be solidified into firm rock they would, indeed, be true conglomerates. Of course the materials vary greatly from the flint puddingstone of Hertfordshire to the New Red Conglomerate of the Keuper, which is largely composed of pebbles and boulders of carboniferous limestone cemented with dolomitic matter. The Bunter conglomerate is largely formed of quartz pebbles cemented with sandstone. Coming more closely to the actual soil, the "muirband pan" formed in some soils by the cementing together of the materials by iron compounds, forms in many cases a true conglomerate on a small scale, though often in a manner very inimical to the developing of the cropping or arable resources of the soil.

LOESS OR BRICK EARTH.—A yellow light-brown or greyish-brown loam, containing a large proportion of calcareous matter intimately mixed with clay. This is the best and most typical material for brickmaking when mixed with a proportion of fine sand, yielding bricks and tiles of a whitish or light colour in contradistinction to those of a red colour obtained from common clay. It is best exemplified in the deposit of the Valleys of the Rhine, the Danube, the Mississippi and the Hoang-ho, but it is also deposited to a small extent in the Medway and the lower Thames Valley, though some authorities actually assert that it does not exist in Britain or France.* On the face of it, however, if the Thames once had the same estuary as the Rhine then the deposits of the Thames estuary would resemble those of the Rhine. But allowing that the brickearth of the Thames estuary is not identical in origin or composition with that of the Rhine does not affect the matter much from our standpoint. The soil on it is a typical loam in the farming sense of the word, and as it occurs near Southend-on-Sea, at the mouth of the Thames, is one of the finest soils in the world, either as regards its physical characteristics or fertility.

ALLUVIUM.—Siliceous sand, mud, and organic matter forming the "earth" of meadows and river sides. It differs from a standard loam in its extra proportion of organic matter, due to its being always deposited by streams or lakes; but it may grade off into other forms, such as clay, peat, sand, gravel, &c., according to

* Geikie (J.): "Prehistoric Europe," p. 150.

circumstances. This is about the only "rock" which exists in a state fit to grow plants without a preliminary weathering and formation of soil on the surface, as it is really ready-made soil material which has been brought down by running water and re-deposited to form the flat tracks in valley bottoms.

SAND.—This may be looked on as sandstone in the loose incoherent state—either before it has become indurated into sandstone, or the débris resulting from the weathering of the same. (Plate I.) It is, of course, most common on the sea shore and on raised beaches, and in some few places along river banks; while, of course, many formations are simply beds of loose sand, such as the Bagshot Sands, the Thanet Sands, &c. It consists of loose, rounded grains of quartz, but sometimes with minute plates of mica and green grains of glauconite, or coloured by iron or manganese oxides.

GRAVEL.—Loose, water-worn fragments of various kinds of rocks, met with mostly in beds of streams, and derived from rocks of the same area. Some authorities describe gravel as composed of "angular" fragments; it is difficult to understand how loose fragments of this sort could retain their angularity, so that the author declines to accept this definition, and begs to adhere to the ordinary acceptance of the meaning of the term as used in the country by those who, like himself, have "raised" flint gravel out of "pits" in the surface deposits of the South of England, and shovelled that of Silurian and igneous origin out of the beds of streams in the uplands of Scotland. Further, many geologists of standing adhere to this nomenclature which is used by country people.*

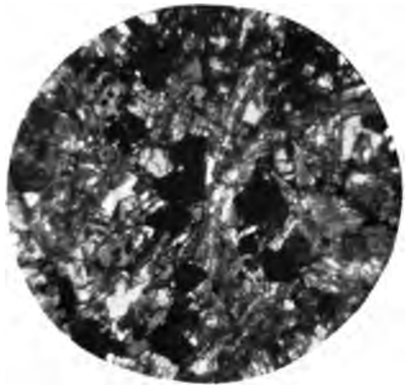
SHINGLE.—The large gravel of the sea shore. It, of course, may be composed of as diverse material as the preceding, differing from it only in size and cleanliness—being better washed as a rule—but it has only a limited agricultural value as far as soils are concerned. In some small areas, such as the shingle beds of Blackheath and Addington in the Lower London Tertiary Age, there is a soil, of course, but more houses than farming thereon. Generally speaking, shingle is of most value to the builder or farm-road maker.

FLINT.—Flint as a rock occurs as nodular masses chiefly in connection with the Chalk-with-Flints of the Upper Cretaceous,

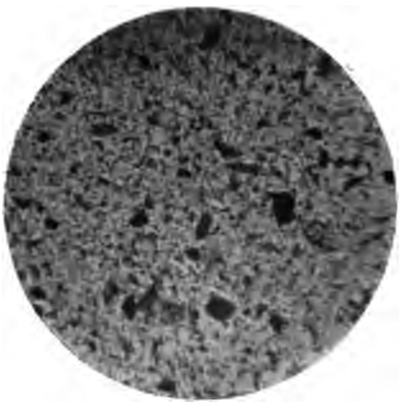
* Page: "Advanced Geology," 5th Ed., p. 92. Prestwich: "Geology," Vol. I., p. 32.

PLATE II.

Granite: Shap Fell.

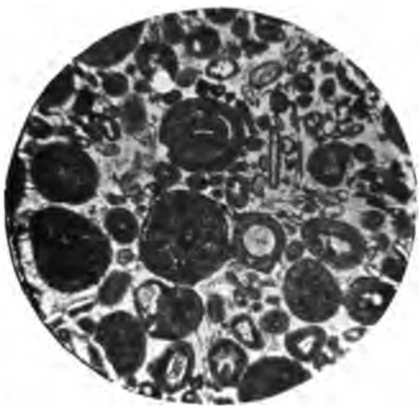


Dolerite: Salisbury Crags.

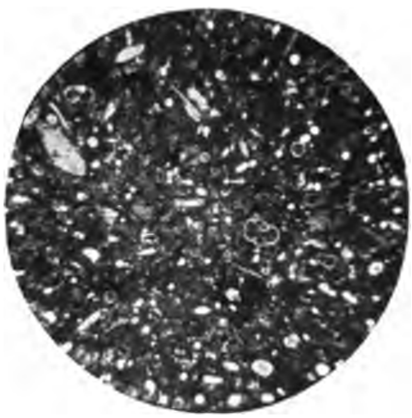


Volcanic Dust: Krakatoa.

Mica-Schist, with Garnets: Perthshire.



Oolitic Limestone: Clifton, Somerset.



Chalk: Missenden, Bucks.

having apparently been deposited by precipitation of soluble silica round some matrix like a sponge, coral, &c. Flints occur in streaks or beds in the chalk, and not all through the mass of the same; and where the chalk has been dissolved away, and left a residue of earthy matter for a soil, the flints form a large part of the same, and a soil with these present in quantity will be more or less stony or gravelly. It is the only material fit to form a wearable gravel or shingle among the newer or Tertiary surface deposits, and all over the south-eastern part of England farmers find that the gravel-pits and even the sand-pits on their farms have a flint origin; the flints derived from the chalk have been carried over and deposited upon the surface of the newer strata of the Tertiaries to the south-east. There is, in short, nothing for road-making or mending in that region but flint-gravel, and County Councils find it necessary to bring in granite and "whinstone" by ship and rail to make respectable roads.

IV. Carbonaceous.

Peat.—This is the only organic "rock" or carbonaceous compound of any importance in farming. It is composed wholly or largely of the remains of generations of plants, mostly of the lower order—mosses, club-mosses, and horsetails—which have been preserved from decay by the presence of superabundant moisture preventing the oxidizing influence of the air from being exercised. The vegetable matter is not much changed on the top parts—indeed, the plants may be still growing on the soft and spongy surface—but it becomes firmer and more compact downwards, and its vegetable structure tends to become obliterated, though before drying it is soft and easily dug. It varies in colour from brown to black, and, of course, is the source of the peat fuel used in many parts of the country. It is a product of temperate and cold-temperate regions in both northern and southern hemispheres, where there is a plentiful rainfall. For its formation the retention of moisture is absolutely indispensable. It consists largely of humus—a substance to which a definite chemical formula cannot be assigned, and with which are associated the various organic acids: humic, ulmic, geic, crenic, and apocrenic.

Dana points out * that in the peat mosses on the limestone regions of Iowa, the Sphagnous mosses are replaced by the Hypnous

* "Manual of Geology," p. 616.

species: it would be interesting to know if this is the case on the limestone regions of Ireland.

Peat is, of course, essentially the same material as the organic matter or humus of the soil, and its presence and the proportion present have a most vital influence on the same. Any soil with more than five per cent. of organic matter present is classed as humous, and there are all possible intermediate stages between this and pure peat. Its most important physical characteristic is sponginess—*i.e.*, the ability to absorb and retain water—and to this quality is due mostly the power of a soil to retain sufficient moisture for the growth of plants. If, however, there is too much water and it is stagnant, then there is the tendency to develop the above-named acids, and the land becomes "sour" and unfit for the roots of cultivated plants. The remedy is draining, to remove superfluous water and to allow the air to enter and oxidize the particles; and also liming, to neutralize those acids and "sweeten" the land.

Peat may be looked upon as imperfect coal: the carbonization is only partial (though there may be over 60 per cent. of carbon present), and there is still a large proportion of the oxygen, hydrogen, and nitrogen of the original vegetable bodies present in it, with, of course, the mineral matter as well. It is antiseptic in its nature, so that the larger parts of the plants associated with it are preserved, such as the trunks of oak, pine, and birch trees; animal bodies embedded in it are also preserved, though the tissues change into a body called *adipocere*.

The oxidation of the carbon is always going on wherever the water is removed and the air allowed access. The growth of the ordinary grass turf of a pasture field forms humus, or peaty matter, from the dead roots and leaves in exactly the same way as in a peat moss, but the comparative dryness of the former and the access of air admits of a concurrent destruction from oxidation, and thus prevents accumulation, so that even an old turf has only a limited amount of peaty matter present. In arable land the humus may all have been thus destroyed, from the cultivation having assisted the oxidizing influence of the air, and one of the uses of a dressing of farm-yard dung is to partially replace this humus.

CHAPTER IV.

PHYSIOGRAPHY OF SOILS.

From a mineralogical point of view the soil is composed of a mixture of weathered fragments and "decomposition products" of various rocks or the minerals composing the same, *plus* a proportion of carbonaceous material; and a given soil will be light or heavy, fertile or poor, as to its own specific composition according to the lithological nature of the formations from which it has been formed. A soil consists of mingled fragments of various kinds, small particles of rock of many varieties, associated with material derived from the breaking down of vegetable and animal remains. Adhering to the surface of these particles, or scattered among them in the form of crystals, are various substances deposited from super-saturated solutions of soil-moisture,* and which show themselves conspicuously as an efflorescence on the surface of some soils as the result of evaporation in dry weather.† Besides this, in clayey soils there is a proportion of pure silicate of alumina among its fine silt-like particles which is sticky or adhesive in its nature. This colloid material, however, never amounts to more than 1·5 per cent. according to Schlœsing, but is sufficient to make a clayey soil stiff and difficult to work.

Besides this, however, geology has more to do with what might be called the physical characteristics, surrounding circumstances, and conditions of any particular field or farm than any other science; and in the practical every-day life of the farmer these are often of more account than the particular composition or fertility of the soil itself.

To begin with, the British Islands themselves are geological facts, and, by inference, everything that is in them or on them is so also; while certainly every rural feature—hill and dale, river, lake, and sea—are all due to the action of geological agencies, so that not only the soil, but all the natural, and even some of the artificial features of every farm are due to or influenced by the geological

---

* King: "The Soil," p. 28.
† Johnstone: "Elements, &c.," 17th Ed., p. 96.

changes which have been going on since long before the advent of man.

As mentioned in a former chapter, when these Islands finally emerged from the northern seas—as part of the continent of Europe before the protecting "silver streak" was formed, when the Thames was a tributary of the Rhine—they were more or less irregular humps of bare, barren rock. The disintegrating agencies immediately began their work, the eroded material being for the most part carried down to the sea by the action of running water supplied by the rainfall. Every natural irregularity of the surface—such as a fault or a crack in the strata—would have the water collecting in it and running seawards, and this, in course of time, would form a regular stream. Further erosion would form a ravine or a glen, to be still further widened out into a strath or a valley by the continual shifting of the bed of the stream wearing away the ground to a bluff at one side, and depositing silt as a level alluvial meadow on the other.

The occurrence of the Glacial Age, lasting into comparatively recent times, introduced another powerful agent in the scooping out of valleys and rounding off of the lower hills, the laying down of clay, sand, or gravel in irregular deposits as sheets or mounds—that of ice moving in the form of glaciers, with the floods and streams resulting from the melting of the same, as already noted in the Introduction. The Glacial Age has had so much to do with the formation of the features of the country and its farming—at least in the northern parts of these Islands—that the different deposits of the same will be treated *seriatim* later on.

All these agencies aiding and abetting each other through countless ages have sculptured the land into its present form, and they still continue to do so, though the rate of change is so small as scarcely to be perceptible in the space of an ordinary lifetime. To their action on rocks of different degrees of hardness is due the existence of the rugged hills of the Highlands, Wales, Wexford, and other parts; the comparatively low-lying and even level stretches of the Midlands, Fens, Lowlands of Scotland, and Great Central Plain of Ireland; all the picturesque valleys and glens; all the lakes of the "Lake Country," the "lochs" of Scotland, and the "loughs" of Ireland.

All these general considerations relating to the surroundings of a particular farm or soil—the features of a countryside—are due to the geological formations below the surface, and the action on

them of geologic agencies, and it is proposed in this chapter to take up these features and conditions as affecting the farming, one by one.

Climate.—If anyone were asked, in a general way, what circumstances most influence the farming of a district, the reply would be "Soil and climate." The influence of geological conditions on the soil we study elsewhere, but here we want to point out to what a surprising degree the climate of a district is dependent on the geology thereof. In fact, the climate in a country of such limited extent as England depends mainly on contour, and this we know to be determined by geological structure alone.* Generally speaking, we may define climate as the particular combination of the natural light, heat, and moisture which prevails in any given district, and the factors of which we may conveniently study from a geological point of view under the heads of the Gulf Stream, Rainfall, Forests, Altitude, Aspect, Proximity to the Sea, and Isothermals.

Gulf Stream.—The Gulf Stream is, of course, the great regulator of our climate generally, bringing the warmth of the tropics to our shores, and while preventing our summers from becoming so hot as continental regions on the same latitude, it tempers our winters so that the average temperature of our coastlands all round these Islands in winter time is much the same—north or south. But we get these benefits because we live on islands set in the northern seas, right in the way of a southern current, and we have just seen how much the existence, extent, configuration, and characteristics are due to the geologic materials out of which they are made and the geological agencies which have made them—the ocean current itself being one of the latter.

Rainfall.—At the first look it would appear to be a rather far-fetched statement that the rainfall depends on the geological formations of a country. If, however, a rainfall map of the British Islands be placed alongside of one showing the geology, and also a third showing the contours or elevations, it will surprise those who have not previously some knowledge of the subject to find that there is a very great degree of correspondence among these three phenomena—that in fact they all hang together. The heaviest rainfalls are on the oldest or hardest rocks, which also form the

*Elsden: "Agricultural Geology of Herts," p. 146. *Trans. Herts. Nat. Hist Soc.*, June, 1883.

highest hills, with one or two exceptions. To put the matter in a general way, all hilly and mountainous districts in these Islands of over 1,000 feet in elevation have over 100 inches in rainfall per annum.* In many cases even the 750 feet contour line is approximately the boundary of the wettest parts. In discussing the question of Altitude it may be pointed out that, with few exceptions, all the land in this country over 1,000 feet high is on the Silurian, Cambrian, Laurentian, or Archæan and Crystalline systems, so that we come back to the fact that altitude, rainfall, and local temperature are all for the most part dependent on the kind of rock beneath, as is the nature of the soil itself.

It may be urged that the greatest rainfall is on the western side of these Islands because the moisture-laden winds blow from the south-west during the greater part of the year, and come first into contact with the high-lying land on the western and southern shores. The reply to this is that the mountains are on the west because they are formed of the oldest and hardest rocks. Indeed, our country owes its very existence and survival to these old bulwarks facing the Atlantic surge. It is held by some authorities that when the Straits of Dover did not exist, and Britain was an integral part of the Continent, the shore line was somewhere near the present 100 fathom line of sea soundings, and that the ceaseless swash of the Atlantic breakers—aided, of course, by the partial subsidence of the land—has washed away the solid earth back to these old, rugged, dour barriers which now make a "scientific boundary" for us. If the North Sea had been as tempestuous, and for as long a period as the Atlantic, the low-lying country on the newer deposits would have all been wiped out as well, and the Lowlands of Scotland and the greater half of England would have been non-existent, and the farming of Britain would never have been a pattern to the world. Even as it is, the comparatively small surge of the North Sea has completely washed away large tracts of land within fairly recent times, such as the town of Ravensburgh, in Yorkshire, where Edward IV. landed in 1471 A.D.; Reculvers, in Kent; and the Goodwin Sands, which latter were solid land in Saxon times.

It is even held by some that the Irish Sea exists because the land there was originally largely composed of chalk and other beds of the newer deposits, and these being softer were more easily

* Keith Johnston: "Hydrographic Map of British Islands."

abraded down by the sea or scooped out by the glaciers coming from the north during the Ice Age.*

It is not a fact, however, that the western side of these Islands has more rainfall than the east, irrespective of altitude, as the following statement of that of certain eastern hills will show. The eastern end of the Grampians and other Highland ranges, the Pentlands, Cheviots, Cleveland Hills (York Moor) have a large rainfall, while in Ireland the Antrim Hills, the Mourne Mountains, and the Wicklow Mountains are as wet as the western ranges; all because they are elevated, and they are elevated because, with a few exceptions, they are of ancient or indurated rocks.

The rugged coast facing the Atlantic breakers has thus preserved the British Islands from utter annihilation in the course of geologic time, while these very breakers have equalized the temperature all over, excepting in so far as it has been modified by the geological structure of the physical features.

It is noticeable that if the annual rainfall is taken by each county across England from Snowdon to Essex that there is a gradual decline from over 100 inches to about 20 inches, and that the corresponding acreage of pasturage decreases as we go east, and the acreage under corn increases. But it is not a coincidence, as it is the cause of the whole of these circumstances—that a journey taken in this direction crosses all the formations in their natural order from the oldest to the youngest, and that it is *downhill* from west to east all the way. The following table shows this gradual scale, how all the items "rise and fall" together:—

	Merioneth.	Montgomery.	Salop.	Worcester.	Warwick.	Northamps.	Beds.	Herts.	Essex.
Percentage acreage under corn...	11·1	20·3	22·4	26·2	25·7	29·8	42·0	42·3	46·3
Percentage acreage permanent pasture	75·9	63·8	58·2	52·9	56·4	52·8	31·4	29·7	24·2
Rainfall: inches per annum—approximate	100	95	45	35	30	27	25	22	20
Average height above sea level—approximate feet	900	700	400	300	270	250	230	220	200
Formations	Primary Rocks.			Secondary Rocks.					Tertiary Rocks.

* Lewis: "Glacial Geology of Great Britain and Ireland," p. 35.

Forests.—The climate, the beauty of the scenery of a district, and the utility of rough or broken land, are all much ameliorated and improved by the existence of plenty of trees—scattered singly or gathered into woods and forests. Strips of plantation or large masses of timber do much to lessen the force of storms if planted on the exposed sides of a district or a farm, while the rainfall and the amount of ground moisture are largely influenced by the existence of the same. It is not desirable to have trees on arable land—either in the hedgerows or singly in the open field—because of their drain on the plant food of the soil and the amount of crop they spoil, but massed in clumps or large stretches their influence is wholly for good. Forests tend to equalize the temperature of day and night in summer; retard the evaporation of water from the soil, thus helping to keep springs going; and most decidedly increase the rainfall. The island of St. Helena was at one time covered with forests, and had an ample rainfall, but the cutting down of the trees reduced it to a barren waste.*

The wholesale cutting of timber in the United States of America has had so bad an effect that some of the States give an extra grant of land to settlers who plant trees, and a national tree-planting day —"Arbor day"—is held every year. Lake Tacarigua, in Venezuela, was gradually drying up in the end of the eighteenth century owing to the cutting down of the rank tropical vegetation on its banks, but when war broke out in the beginning of the last century—lasting 22 years—and the forests again sprung up, the waters of the lake accumulated and covered land which had formerly been under cultivation. The river Scamander in the Troad has dried up, and the Euphrates contracted perceptibly owing to the cutting down of forests in their drainage area under the rule of the Turks.†

From these examples will be seen the great influence that forests have on a district and its farming, while, conversely, the district has an influence on the nature of the forests. As the roots of trees go down much deeper than other plants they are much more likely to be influenced by the nature of the rocks *in situ* than the surface vegetation, and we thus find that some trees are more suitable to certain formations than others. The following table

---

* Gaye: "World's Great Farm," p. 119.
† Buchan: "Meteorology," p. 50.

was compiled by the late Professor Buckman to illustrate this, the figures representing relative values:—

Rocks.	Apple.	Pear.	Oak.	Elm.	Beech.	Pine.
Chalk	2	0	2	4	8	5
Greensand	3	1	3	7	0	3
Gault	4	1	6	6	0	0
Oxford Clay	6	0	10	8	0	1
Oolite Freestone ...	2	0	1	4	10	5
Lias	10	3	5	10	0	1
New Red Sandstone Marl	8	0	7	12	0	2
Mountain Limestone...	1	0	2	2	3	1
Old Red Sandstone ...	15	8	8	10	0	1

Merrill, again, acknowledges* that, while he believes in the futility of collating soils to their parent rocks, yet the "residual" soil of any geological horizon may have characteristics adapting it to plant growth of a particular kind; and instances Central Kentucky, where, within a distance of a few miles, there are several distinct geological formations each with its own soil, and with a natural forest growth so peculiar to itself that each formation can be traced for miles solely by the trees on it. King, again, gives† 20 illustrations of the timber growth being influenced by the soil occurring in Alabama, Florida, Georgia, &c.

Altitude.—As we go inland from the sea level we go upwards until we reach the crest of the country or watershed of the district. This does not mean that we encounter actual mountains, or even hills, but elevated land, and as there is a well-known law of climate that as we ascend from sea level the temperature falls, we thus find that the climate is colder on the uplands and hills. The average fall of temperature is 1 deg. Fahr. for every 300 feet, and as a very large proportion of our land is over 1,000 feet above sea level it will experience a temperature of quite 3 deg. Fahr. lower than the same district at sea level.

We are only at this point studying the climatal influence of height above sea level without reference to the nature of the

* "Rock Weathering," pp. 388 and 389.

† "The Soil," p. 82.

ground, hill, or mountain, which gives the height, but it is the crystalline and older indurated rocks that have the highest altitudes, with all the corresponding miseries of a lowered temperature, a scantier soil, steeper land, less nutritive or satisfactory herbage, and a greater rainfall; for "a drink of water and a grand view" will not make sheep and cattle thrive and put on flesh. In such districts—to use the words of the famous geologist, Hugh Miller, when speaking of the Caithness evictions of the crofters of a bygone generation on the bleak Archæan rocks of the north-east—"everything is stunted *except the men*."

Wheat refuses to ripen at a greater elevation than 600 to 700 feet in this country (excepting in favoured southern districts), and 1,500 feet is the utmost limit for even our hardier crops—indeed, for certain and successful results 800 feet is high enough in Scotland to 1,000 feet in England—though some individual districts are more favourably equipped as to soil and surroundings than others.

Aspect.—A hill, or a range of hills, has always got several sides or slopes, and as the sun shines in the heavens from the east round by the south to the west—*i.e.*, when he shines at all—it follows that the northern side of a hill, besides being more exposed to the cold storms which come from the north in winter, receives much less of the sunshine, when there is any in our salubrious climate. Indeed, in the winter time, when he is low in the heavens, even at mid-day the northern slopes may never get any direct sunshine at all. This means a very great drawback to both the plants and animals of the farm. The pastures on the northern side of a hill are more liable to become fogged up with moss than those of the same quality of soil having a southern aspect.

When the slope of the ground is at right angles to the rays of the sun—*i.e.*, about 25 to 30 degrees—it receives the maximum amount of heat, but a slope of this angle would be rather steep for comfortable farming, although steeper fields than this are ploughed with "one-way" ploughs. A gentle slope facing the sun is the most suitable, while a slope away from the sun is undesirable. The difference may be seen any winter time by noting the different rates of the melting of the snow according to the aspect of the ground on which it lies.

On the newer formations over the southern and eastern half of England, in the Lowlands of Scotland, and the "Central Plain" of Ireland the effects of aspect do not come out in such bold relief. These more recent formations are of softer material, have been

more readily denuded, and consequently there are no "mountains," but only "hills" and undulating ground, so therefore one situation is almost as good as another in this respect; but on the older and more rugged formations the aspect of a house, a field, or a farm is one of supreme importance, and in fact in this matter everything is thus everywhere controlled by the formations below —azoic, primary, secondary, or tertiary. But, curiously enough, the aspect has much to do with the actual texture and composition of the soil. The rainfall beats with greatest force on the side of a hill facing the south-west in this country, because that is the direction from which most of our winds and rains come, and thus the light clay or fine earth is more washed out and the soil is more sandy or granular than that with any other aspect. Perhaps this is one reason why herbage on the north to east side of the hills of some of our sheep-walks is sometimes of a finer quality than that on the sunny side.

Proximity to the Sea.—Following up the general principle that the conformation of the British Islands is due to geological agencies acting on geological materials throughout geological time, we are necessarily led to class proximity to the sea—with all that it means in farming matters—as a dependant also on geological conditions.

Proximity to the sea means a higher and more equable temperature than is met with inland and on the uplands: the shore temperature is higher in winter and lower in summer than that in the same district but at a distance inland. We need not go into details as to how much this means to the farming—the absence of the rigours of a continental winter such as regions in the same latitudes in America and Europe experience—for it is here only needful to point out that the sea has been washing and grinding away making these two larger Islands with a host of smaller ones, cutting through and forming the middle stretch of the Irish Sea and all the multitude of openings and bays running into the land, and thus carrying its ameliorating influence far inland. This action has been largely aided and abetted by the action of glaciers in the northern parts, forming the sea-lochs or fiords of Scotland, or, at least, widening and deepening the same, and thus making more sea coast.

Isothermals.—While there is a great difference between the climates of different localities in these Islands, there is at the same time a wonderful amount of equability. The average temperature of the summer is higher in the south than in the north according

to the latitude of a district, and is highest in the south-eastern part of England; round London, at a distance from the sea, where it is not too high above sea level—ranging from 64 deg. Fahr. in that district (and also at the extreme western point of Cornwall) to 52 deg. Fahr. in the Shetland Islands. In winter time, however, the equalizing power of the Gulf Stream shows itself, and the temperature of the coast remains the same from north to south. The east coast average is 37 deg. Fahr., and the west coast 39 deg. Fahr. —two degrees higher. The central part of Ireland averages 39 deg. Fahr., while the south-west part rises to 43 deg. Fahr. in the winter, as it also does in Pembroke and Cornwall. Going into details, we find that in the Archæan, Cambrian, Silurian, and other mountainous regions high up above sea level, the winters are more severe than on the low-lying newer formations, solely because they are high and exposed; for the occasional snowing-up of a train in Devonshire and the freezing-up of the Thames and other rivers in the south, show that the south can occasionally equal the north in this respect. In fact, on the average, the month of January is warmer in the north of Scotland than it is in the Midlands, and the cold winters of some northern and midland districts are the result of their elevation and position, rather than of any difference of latitude. The country extending from London to York through the middle of England has really the lowest winter temperature of the kingdom in proportion to its altitude.

Wheat, in England, requires an average summer temperature of at least 58 deg. Fahr. This means that it cannot be cultivated over 600 feet, as 60 deg. is required to ensure that perfection sufficient to justify cultivation. A deficiency of even 2 deg. is sufficient to cause a deficiency in the crop, and in 1812, when the temperature only averaged 57·2 deg., the nation was on the verge of famine. In Scotland, a temperature of 56½ to 57 deg. is sufficient, for the reason that the summer days are longer, and thus the total solar heat received is the same or more than on land further south. This fact, coupled with the existence of the "warm" fertile soils of the Old Red Sandstone explains why wheat can be grown so far north as the Laigh of Moray and the adjoining Old Red Sandstone districts.

Contour.—The general contour of any particular district or country is a matter which intimately concerns the farming of the same and which is wholly due to, or influenced by, the geological structure beneath and the denuding agencies which have been at work. So intimately, indeed, is the contour connected with the

arrangement of the varying qualities of soil on the outcrops of the different strata, especially in the southern half of England, that Arthur Young, in his journeys a hundred years ago, formed the idea that the nature of the soils of any district was wholly dependent on the contours of the same.* William Smith had not made his investigations then, and nothing was known of the regular superposition of strata in the geological series. The characteristics of each formation in this respect will be noticed in due course, and it is here only necessary to point out the general facts pertaining thereto.

The older and harder strata are characterised by the existence of hills and uneven ground generally. Every hill has at least two sides, and it is manifest that both cannot have the same exposure to sun and weather. The sun occasionally shines in the south, and consequently the southern side of a hill is likely to get the most direct sunlight, with all the benefits to farming that that implies, as already detailed; while, as it is only wild asses that can sniff up the east wind and thrive on the same, and not any of the domestic breeds of Britain, it follows that the western side is the best—or from south round to west to get all the benefits of wind and weather.

Again, hills mean altitudes of various degrees, and just as the average temperature falls as we go north, so it also falls as we ascend a hill, till the line of perpetual snow would be reached if we could go high enough. This, of course, has a corresponding effect on the farming flora and fauna, and the system of management suitable for the valley may not do for high up on the hillside. Now, hills and mountains are features which vary according to the nature of the strata underneath, so that we come back to the datum that the contour of a district determines the farming very much, and the contours are determined by the nature of the rocks. In the newer formations—such as are met with in the south-eastern half of England—the hills and hollows are gentle and undulating, so that altitude and aspect have little or no influence, as, indeed, they can scarcely be said to exist. A north-countryman, for instance, might walk over the Gog Magog hills and be quite unaware of the fact; so that in this matter of the position of a soil or a farm, geology supplies the key of knowledge—apart altogether from the nature of the soil itself.

Coming down from generalities to particulars, it will be

* Woodward: "Geology of England and Wales," p. 548.

convenient to study the general subject of Contour under the headings of Mountain Ranges; Plains; Rivers and Valleys; Lakes, Marshes, and Bogs; Meadows and Carses; Terraces.

Mountain Ranges.—The most conspicuous features in most landscapes are the mountains or hills forming part of the same. Mountain ranges have been called the "backbone" of each country in which they exist—a name that is particularly appropriate in Britain—but the effect of these on the farming of a district is the point of view from which they must be looked at by the farmer. It is evident that the systems of farming pursued on the deep and more or less level soil of the valleys cannot be followed on the hillsides or high-lying moors where the soil is thin and scanty, and where all the fertility has been washed out of it downwards to the levels. For one thing, the natural vegetation is quite different; trees, herbs, and grasses of different species gradually change as we climb from the valley upwards. Even if the soil were equally alike all over there would still be this variation in the natural plants as well as in the cultivated crops. The existence of a mountain or hill signifies altitude above sea level, combined with more exposure to storms at intervals, and this has a corresponding effect on the vegetation, not merely on a grand scale on the great mountain ranges of the world, but on every hill worthy of the name within the British Islands. Without going too much into detail it may just be pointed out that on the higher grounds only the hardier grasses, such as Sweet Vernal (*Anthoxanthum odoratum*) and Sheep's Fescue (*Festuca ovina*) among the better grasses; and Wavy Hair-grass (*Aira flexuosa*) and Mat-grass (*Nardus stricta*) amongst those of an inferior quality—will thrive; while the cultivated or "artificial" grasses will not live—or at least become stunted—at over 1,500 feet above sea level.

But the existence of a mountain is not an accidental circumstance, depending as it does on the nature of the strata beneath. The materials out of which mountains are made have been classed into two kinds, Crystalline and Fragmental*—the Crystalline being generally the oldest, but not always,—and these two types of rock seem to form the bulk of the cores of all great mountain chains. The Fragmental or Sedimentary must have first been deposited at the bottom of seas and afterwards elevated to a greater height than they at present appear, while the Crystalline must also have been

* Geikie (A.): "Mountain Architecture," p. 5.

elevated by the internal forces of the earth. Given that both kinds of mountains were elevated to the same height, and subjected to the same disintegrating agencies for the same length of time, then the crystalline will be eroded the most slowly, will yield the most rugged and picturesque country, with the highest elevations, the thinnest soils, the most broken land, and, generally speaking, the most undesirable places to farm in; forming districts where you cannot get a good-sized field without it being excessively steep, broken up with projecting rocks or loose boulders, and the soil thin and probably poor. To simply mention the crystalline or metamorphic mountains and hills of the British Islands—without going abroad—is to name the districts known to all farmers as those of the most exposed, wild, and rugged character, devoted to sheep-farming with the mountain breeds, and to the rearing (but not the "feeding") of the hardier breeds of cattle. Such districts are the Highlands of Scotland, with the Western Islands; the "Southern Highlands" (culminating in the hills known as Merrick, the Cairnsmuirs, the Leadhills, Ettrick Pen, and Lammermuirs); the "Fells" and rugged hills of Cumberland and Westmoreland; the "stormy hills of Wales"; Dartmoor; the Wicklow Mountains; the wild rugged districts of Connemara, Mayo, and Donegal; the rugged plateau of Antrim; and the peaks of the Mourne Mountains. The material out of which these are made is not always, of course, actually "crystalline"—such as granite, syenite, porphyrite, diorite, basalt—as some of them may be composed of the intermediate metamorphic rocks of the older formations of the Archæan, Cambrian, and Silurian; but the common feature of all these is that the rock material is hard and indurated as compared with the newer sedimentary formations. The farming peculiarities of each will be touched on in a succeeding chapter, so at the present point it is only necessary to summarise the facts that the older and harder formations give us the ruggedest parts of the country with special breeds of live stock adapted to the same, with the natural pasture or cultivated crops of special varieties or species, and little or no actual arable farming.

On the other hand, the newer Sedimentary or Fragmental formations yield scenery and physical pecularities of a much more "tame and domestic" character, but correspondingly better adapted for the cultivation of domestic animals and plants—in short, for ordinary agricultural farming. To those already acquainted with the farming of the different districts of this country it is sufficient

to mention some of the hilly (but not mountainous) regions on these formations to exemplify such, and though in some instances these districts might almost be classed with the former division, yet the type is much more "mild" in its style; such as the Pentlands, part of the Cheviots, the Pennine Range, York Moors and Wolds, Lincoln Wolds, East Anglian Hills, Chilterns, North and South Downs, Mendips, Cotswolds; in Ireland, the Galtee Mountains, Macgillicuddy's Reeks, Knockmeledown, Slieve-Bloom, Carnmore, and so on.

Some of these are of comparatively little elevation, while arable farming can be carried on almost to the summits where the nature of the soil allows of it, as there is often land of easy slope unbroken with rocks, and with good deep soil on the same.

As regards age, the mere height or size does not give any indication. The Scottish Highlands, for instance, are much older than the Alps, Himalayas, Rocky Mountains, or Andes, as these latter were all upheaved in Tertiary times,* and therefore the former are much more denuded.

Plains.—There are three kinds of plains recognised by physiographers—plains of deposit, plains of denudation, and plains of volcanic origin.

Every wide valley and estuarine deposit may be reckoned a plain of deposit where its area is large enough, so that in this sense all meadows, fens, carses, &c., may be classed as plains, though we have to go abroad for the largest and most striking examples. Plains of deposit occur in such cases as the valleys of the Po, of the Nile, of the Ganges, and of the Red River, and indeed in the case of all the large rivers of the world, yielding land of the best quality for farming purposes, easily cultivated, but in many cases subject to inundation, swampy, difficult to drain, and often unhealthy—at least in tropical and sub-tropical regions—from the miasma arising. Such plains have been formed from the deposit of the silt at flood time, but on a more gigantic scale than in the case of a meadow; and the deposition is sometimes artificially helped, as in the case of the Nile, where the muddy water is pumped up on to flats at a higher level than the ordinary floods reach.

The Red River Valley in North America is an exceptionally good example of a plain of deposition, as it is believed to be the

* Geikie (A.): "Mountain Architecture," p. 17.

bottom silt of an immense temporary lake, named Lake Agassiz, formed by the melting of, and damming up by, glaciers at the close of the last Ice Age, and thus yielding soil of exceptional depth and richness, but clayey towards the margins, as is the case with all river deposits.

Plains of denudation are represented in Britain by such districts as the Great Central Plain of Ireland, the Cheshire Plain, the Yorkshire Plain, the East Anglian Plain, and Salisbury Plain. Such districts are, of course, undulating, and permeated by river courses with their line of meadows, but the distinctive feature is that they are more or less low-lying as compared with actually hilly ground ; that they exist on the softer and newer strata ; and that they have been made as we now see them by denudation or eroding of overlying material, or weathering down of the rougher features. On such the soil is deeper and richer than on hilly land in the neighbourhood, partly because the greater weathering or denudation has supplied more surface material out of which a soil is made, partly because the flatness of the land has allowed this material to stay where it was formed since the present geological period began, and partly because this eroded material being formed of the marl, sand, chalk, gravel, limestones, and clay of these newer strata—either singly or mixed—is more fertile of itself.

Plains of this kind are more conspicuous abroad, however, and outstanding examples are to be found in the prairies of North America, the pampas of South America, the steppes of Russia, and similar regions. The fertility of the soils of these regions is phenomenal where the rainfall is sufficient, but here the point we are concerned about is the fact that they all occur on the newer and more easily weathered formations; the prairies on the Cretaceous, the pampas on the Tertiaries, the steppes on both of these, and so on similarly of all other plain regions. Whatever their original form when elevated into dry land, and however the surface soil was formed, and whatever its quality, their soft material weathered down easily so as to make great reaches of more or less level or undulating land, exceptionally well fitted for arable farming, and for the making of big fields or "sections" to suit wholesale gigantic crop growing, excessively cheap production of corn, and the depression of agriculture in our own little country.

Of the third kind of plain—that of volcanic origin—the basaltic plateau of Antrim is the nearest approach in the British Islands. This cannot now be called in any sense a plain, however, because,

although originally no doubt laid down as approximately level sheets of basaltic lava over the chalk, lias, and other formations down to the Silurian, it has since been sculptured in many places into deep valleys and ravines, with rugged hills here and there ; a large part, however, being fairly undulating and suitable for arable farming.

Rivers and Valleys.—A river must always be accompanied by a valley, and *vice versa*. The valley may be as narrow as a cañon or a glen, or as wide as a fen or a strath, or even a "rolling" region tending to be as big as a prairie. Valleys are all more or less the result of erosion, either by the river now in them, or by the ice in former ages, or by the action of both together. Thus the river is a geological agent, and the formation of the valley is the work which it has done. Its value for watering purposes, for draining away water and thus lessening the amount stagnating in the soil and rendering the same more fit for the growth of animals and cultivated plants, its use as a motive power, are all subsidiary adjuncts though of great importance.

The general course of a river is at right angles to the direction of the range of the hills, and, of course, downhill, so that the land tends to be cut up into cubical or pyramidal masses, which the concurrent aerial denudation rounds off into hills. When a boss of land is elevated above sea level, the rain-water will tend to collect into streams running parallel to one another, and down from the highest watershed. Each stream will in time carve out a valley, not only by the wearing action of the water in the water-bed itself, but also by the action of the weathering agents causing the material of the sides of the valley to be loosened and carried downhill into the stream, thus widening the valley and reducing the slope of the sides to a lesser angle. In this way a "cwm" or coombe is developed, and a typical valley is formed on these lines. Where the rocks are very hard or the atmospheric weathering *nil*, then a cañon is formed, as in Colorado, where deep, perpendicular-sided ravines have been cut by the wearing action of the water in the river bed alone.

When the valley-heads or coombes wear through the central ridge into one another a "col" or saddle-back is formed, with a peak or hill left at the edge or in the "corner" between the rounded heads or coombes, so that thus a central ridge of elevated land becomes cut up into a row of peaks more or less regular or

irregular according to the nature of the strata and other subsidiary factors.*

The longitudinal and the cross sections of the surface of a valley always show a curve—called the "curve of denudation." (Fig. 3.) The valley bottom may be almost level at the sea end, or at the river bed (viewed transversely), but it rises with a gradual curve as it approaches the hills, till it may become almost perpendicular if followed to the hilltops at the head.† Differences in strata, in vegetation, and in other matters may modify this in details, but viewed from a distance, or as a whole, it will be found that every hillside—or valley bounded by the same—approximates to this elliptical or parabolic curve. The principal causes of deviation

FIG. 3.

PARABOLIC CURVE OF DENUDATION.

are alternations of hard and soft strata weathering unequally, a covering of earth and vegetation—especially peat—protecting the top, and the difference of exposure to the south-west as compared with the north-east. Every hill tends to weather into a sharp, pyramidal peak, running into the curve of denudation at the bottom. Vegetation will check this and keep the tops rounded, as in the Cheviots; or the extra moisture on the south-west side will develop vegetation to a greater extent, and so there will be a rounded convex top in that direction, and a steep, concave-curved slope on the other side, as exemplified in the Moels of Wales.‡ Farms, therefore, situated on the south-west side of hills will have

* Marr: "Scientific Study of Scenery," p. 75.
† Ibid., p. 127.
‡ Ibid., p. 87.

less steep and rocky land and a greater depth of soil, though perhaps of a poorer quality owing to the extra "washing" it has received, besides a better exposure or aspect than those on the north-west side.

It is noticeable that all the great wide plain-like valleys are found on the newer formations, as in the south-eastern half of England, and for the same reason that there are no very high hills there—*i.e.*, the comparative softness and easiness of erosion of the rock material—while the narrow glens, ravines, and dales are among the older and harder rocks.

It sometimes makes a considerable difference to the climate of a valley whether it is "end-on" to the sea or runs parallel to the shore of the same.* In the former case it has a greater share of meliorating sea breezes, rain-clouds will not be robbed of their burden by an intervening hill, and the natural vegetation and farming consequent thereon will be modified.

In the case of the British Islands, the predominating winds bearing rain-clouds are from the south-west, and the Gulf Stream comes from pretty nearly the same direction, so we might look for some superiority in this respect in valleys which open to the west or south-west. Undoubtedly there is some difference in favour of this state of matters, but these Islands are, so to speak, comparatively too small to give room for great variations, and there are so many other cross-influences at work that the author is not able to give definite figures for any one valley as against another.

Lakes, Marshes, and Bogs.—The existence of these influence very unfavourably the climate and the farming if in the vicinity of any district. They give rise to night fogs—especially the two latter, as in these the water is more stagnant than in the case of lakes,—lower the general temperature of the district, &c., though they may add to the scenic beauty of their neighbourhood.

A marsh is, in general terms, a lake which has become silted up more or less, or a section of ground where the water has not yet cut for itself a definite channel, and where it spreads out and soaks and flows over a certain area of ground wide in proportion to its length.

A bog is practically a marsh which has been formed not by the silting up of a lake, but by the growth and accumulation of peat-moss. There is, of course, difficulty in drawing a distinction in

* Page: "Geology," p. 39.

many cases, because the one often merges into the other, and some areas have been alternately marsh and bog—as, for instance, many of the alluvial meadows of Upper Nithsdale, where there is about a foot of alluvial silt of recent deposit, beneath which there are many feet of pure peat, and a deep furrow made with the plough is enough to turn up the black peat with sticks and timbers (birch and hazel) galore. Another good example where the one can be compared with the other occurs in the Fens of Cambridgeshire, where the peat yields a soil of second-rate quality, but adjacent stretches of alluvial silt are of the best quality and suitable for the growth of special crops like mustard.

The discussion of these soils will come in their proper order, and it is here only necessary to point out that the climatic influence of lakes, marshes, and bogs on the farming of a district are similar, and that they have similar geological bases.

There are about six different kinds of lakes—not including those of salt water—all owing their origin and existence to geological agencies. There are, for instance, those due to (*a*) the damming up of a valley by a landslip; to (*b*) the accumulation of sand and gravel débris from the melting of glaciers holding the water in the hollows, as among the great gravel mounds of Carstairs, Lanarkshire; to (*c*) glacier erosion, in which the hollows have been scooped out of the solid rock by the long-continued action of glaciers, as we find is the case with most of the sheets of water of Scotland, Cumberland, Wales, and other elevated regions; to (*d*) the elevation of ridges of land by seismic forces, damming up the water, and so on.

Many of the wide, level, alluvial plains to be met with in different regions have been formed wholly from the silting up of an ancient lake, though the general character of the same may have been considerably altered by subsequent cutting of the channel of the river, and its shifting about from time to time.

Marshes and bogs are very unhealthy neighbours to have because of the fogs and miasma constantly arising from the same. A lake is only less so, and the presence of all or any of these tends to lower the temperature and increase the rainfall. It is jocularly said by the farmers of Antrim that their wet weather comes out of Lough Neagh, and that if they could put a lid on it they would be able to regulate the rainfall to suit themselves. As this is the largest fresh-water sheet in the British Islands there is a good deal of truth in the statement, while if the district were not a basaltic plateau,

there would probably be no "lough" at all, because the underlying Cretaceous and Oolitic formations would have worn away so readily as to prevent the imprisonment of water in a lake.

The evaporation of water is more from a thin layer, such as a marsh or bog, than from a deep lake, so that while the neighbourhood of a large lake tends to equalize the temperature, the proximity of swamps lowers the same.

It may be useful to here note that the evaporation of water per month from the surface of a lake or pond varies from ·57 inches in December to 3·44 inches in July, from observations taken near London ; the total for the year being 20·66 inches.

Meadows and Carses.—Intimately connected with the valleys and rivers, and the eroding and depositing action of the latter, are the meadows, holms, haughs, and carses met with along their courses. The first three are names given by farmers in various districts to alluvial deposits along the course of a river, while a "carse" is a level district of estuarine origin—a deposit formed at the mouth of a river in fact. These formations have, of course, been due to the depositing of the sediment of the water, and it is instructive to note the amount held in suspension by some of the principal rivers of this country, and compare this with the nature of their deposits and the farming of the same. The following table gives a comparative statement for five of our rivers :—

	Length. Miles.	Drainage Area. Sq. miles.	Annual Discharge of Water. Millions of cubic feet.	Annual Discharge of Sediment. Cubic feet.	Cubic feet of Water to one cubic foot of Sediment.
Tay	90	2,090	144,020	49,660,000	2.900
Boyne...	63	1,046	94,614	36,622,000	2,500
Clyde	90	1,145	25,228	8,699,000	2 900
Forth	60	496	15,450	5,328,000	2,900
Nith	55	493	14,000	3,645,833	3,840
Thames	200	5,162	54,111	1,865,900	29,000

It is instructive to note that the Thames—which is the longest river, and the one with the largest drainage area on the above table—has the smallest amount of silt or sediment carried in its water. This is an illustration of the fact that the sediment and

the material carried in solution are two different things. The Thames drains a large area of chalk and limestone, large quantities of which are annually carried down by its water, but in a state of solution, thus adding little to the solid silt out of which meadows and similar formations are made. In the following table are given some figures to illustrate the amount of soluble material carried in river water per 100,000 parts* :—

	$CaCO_3$	$MgCO_3$	$CaSO_4$	$MgSO_4$	Na Cl, &c.	Si, Fe, &c.	Total.
Dee	1·22	0·20	0·17	0·46	0·96	0·11	3·12
Danube ...	8·37	1·50	0·29	1·37	trace	0·89	12·42
Rhine ...	12·79	1·35	1·54	0·29	0·15	0·90	17·12
Rhone ...	14·10	—	1·40	1·60	0·10	1·00	18·20
Thames ...	16·84	1·81	4·37	—	1·57	2·61	27·20
Seine	17·40	6·20	3·90	1·70	1·70	1·40	33·10

If the area of the level districts belonging to any river be noted, it will be found to correspond to the amount of silt per annum carried down in the water—with some exceptions, as in the case of the Boyne. With this river there is, however, a pretty large area too, but its greatest extent of valley is the bog-land in Meath and West Meath, and the greater part of its sediment seems to be carried out and swept away by the cross-currents of the Irish Sea —this state of matters being aided by the steep descent of the latter part of its course, where it is confined between hills leaving comparatively little space whereon to accumulate soil.

Where the descent is thus steep the meadows or alluvial tracts are small, as conversely the valleys are more or less narrow gorges in the older rocks, because it is among the older rocks only that steep and rugged watercourses are possible. Among the newer rocks of Mesozoic and Cainozoic age the country is more level, the water runs more slowly, has room to spread more widely, and therefore the alluvium is of greater extent and its effect more pronounced in the matter of meadow farming.

Before illustrating these facts and noting their farming significance, it must here be explained that between the ordinary valley alluvium and the estuarine deposits there is a marked difference,

* Prestwich: "Geology," Vol. I., p. 106.

though the one kind may graduate into the other. This is due to the power of running water to not only carry sediment, but also to carry along stones and gravel; the stronger the current the coarser the material, and *vice versâ*. The effect of this is to cause the stones, pebbles, and gravel to be deposited in the upper reaches of rivers where the descent is steepest and the current strongest, whilst the finer matter—sand and silt—is carried lower down and left on the banks in the more level country; and the finest matter of all—the impalpable clay—is carried out to sea, or at least to the river mouth or estuary. Where there is a sudden change from a steep waterbed to one more level, there is apt to be deposited mounds, ridges, and beds of coarse gravelly material, forming dry, barren hillocks in the fields. In the course of a river from source to sea there are, therefore, likely to be three kinds of soil or surface materials forming its flats, now or formerly within the flood-mark. In the upper reaches the meadow land will be sandy, gravelly, and stony—that is, of course, infertile material, poor in itself, and incapable of holding manurial material for any length of time. Further down the course, where the current moves more slowly and the water has room to spread more widely in flood time, the soil deposited more nearly approaches to a normal loam composed of finer "silty" matter, and, as far as texture and composition is concerned, is the best soil of the district, though often unsuitable for arable work on account of want of drainage or from being subject to floods.

Lower down, at the mouth of the river, the finer material and clay becomes deposited in clay beds, as exemplified in the case of our "Carses." Whenever fresh water containing fine matter in suspension mingles with the salt water at the mouth of a river, there is a precipitation of the suspended matter from the chemico-mechanical action of the brine "flocculating" the same. In this way the "bar" of a river mouth is formed, and if this is not artificially removed by the dredging operations of the harbour authorities, or naturally by cross-tidal currents, it accumulates in the course of generations and forms a level stretch of land—generally of a clayey nature if there is any clay material at all up the river course.

The fact that the clay is carried furthest and deposited at the mouth of the river is well exemplified in the Carses of Gowrie and Stirling, Sunk Island in the mouth of the Humber, the mouth of the Thames, and some of the "Slob" lands of Ireland—*i.e.*, land

reclaimed from the sea in the various estuaries – in all of which the soil is either a very stiff clay or of a clayey texture.

Deposits such as the warp land of the Ouse and associated rivers, the Fen country, Romney Marsh, the levels of Somerset, the "haughs" of the Clyde, and many others, exemplify the formation of the best alluvial loam of the middle part of the course of a river; while the meadows in the upper reaches of almost any river in the British Islands exemplify the first, or coarser form of alluvium, such as met with in the small, gravelly flats of the Nith and Afton in Ayrshire.

Terraces.—A particular form of alluvial deposit sometimes found along the sides of valleys calls for notice on account of the influence it has on the fields and soils and general conditions of farming.

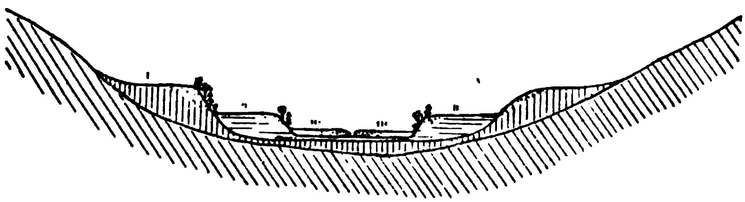


FIG. 4.

TERRACE FORMATION IN VALLEY.

This is the terrace or "bench" formation of the ground. At a former period in the history of many of our valleys, they were filled up more fully with silted material, owing mostly to the fact that the rainfall was greater, or the water from the melting of retreating glaciers was in greater quantity than the amount which flows now. The floods then brought down more silt, and spread right across a valley, from hillside to hillside. A lessening of the supply of water enabled the river to cut a smaller course and begin the erosion of material laid down in the former period, and thus cut out a smaller valley within a valley, as it were, leaving bluffs which form the edges of these smaller valleys. This process has sometimes been repeated several times, so that there may be a succession of these terraces one above the other. The general

features are, that in going from the higher ground towards the river we encounter a more or less level stretch of land very suitable for arable farming, then a bluff or sudden steep slope—generally planted with trees on a carefully managed estate—leading to another level stretch, and so on till we come to the river itself. (Fig. 4.) But a special point about the nature of these soils is that they have been deposited in the same order and from the action of the same physical laws as we find in the case of meadows generally from source to mouth of a river. When a river expands in flood time widely over a valley, the most rapidly moving water will be in and near the actual channel, and thus the gravel and coarsest material will be deposited near there. On the other hand, the extreme limits of the flood will be formed by water in very slow motion, and thus the finest or clayey material will be there deposited—with sand or loam in the middle part. Thus, the highest terraces will be of the most clayey nature, and nearest the hillside, while the part of each terrace furthest from the river will be more clayey than the side nearest the same, and so on until we come to the most sandy or gravelly part close to the bed of the stream. This arrangement is found more or less on every river in Britain, and perhaps in the world, while a typical illustration of this will be found in Clydesdale, where the farms, fields, fences, plantations, the texture of the soil and cropping of the same are all modified by and dependent upon this arrangement of these special alluvial terraces. (Plate VII.)

Soil Characteristics.—It appears desirable at this point to take up certain matters regarding the nature of the soil which are directly due to the geological origin or connections of the same, and because such form physical characteristics which have much to do with farming.

It has been pointed out that the chemical analysis may be misleading, and that the mineralogical analysis cannot yet be satisfactorily made; but we can examine certain of the components of a soil which are visible to the naked eye—which, indeed, form the tangible material soil, and which determine the general nature of the same.

The ordinary "proximate constituents" of the soil, as given before, are sand, clay, limestone, humus, and gravel. And on the relative proportions of these depends the ordinary texture and nature of the soil, and from these the farmer ordinarily judges of

the arable qualities of the land. Where any one predominates, the soil, in the language of the farm, takes its name from the same, while there may be any number of intermediate varieties, such as Loamy (sand and clay), Marly (clay and limestone), and so on. Exact percentages of each cannot be given, as a classification of the same, according to exact figures, would not accord with any actual soil, and might be misleading.

Sand itself is nearly always minute rounded fragments of silica, but it may sometimes be micaceous and sometimes formed of minute fragments of other undecomposed mineral matter. It has, of course, no cohesive or adhesive power, and very little capillarity.

Clay, on the other hand, is the converse of this. It is plastic from its chemical combination with water, and is the principal constituent of the soil, giving it its retentive power, and entering into the formation of "double silicates" with manurial or fertile ingredients.

The physical characteristics of soils may be conveniently studied in detail under the heads of Structure, Depth, Size of Particles, Capillarity, Texture, Tenacity, Colour, and Temperature.

Structure.—The soil and surface accumulations are always arranged in a certain order wherever there has not been any disturbance of the same. If a section be exposed it will always be found that the layers occur in the following order:—On the surface there is about three inches of turf, composed largely of the matted roots of the vegetation. Below that comes the soil proper, varying in depth from a few inches to over a foot, and generally darker in colour than the layers below, from the presence of a proportion of humus or organic matter. Next in order comes the subsoil, generally much lighter in colour than the top part, from the absence of organic matter, less fertile, and more likely to contain poisonous or unoxidized substances such as sulphide of iron, and forming in reality the basis of mineral débris out of which and on which the soil has been made. Below that again we come to the solid rock of the locality, forming the "solid geology" of the maps, and which gives the character to a district and the soils found therein. Between the subsoil and the rock there is generally a mixed formation called the "brash," or rubble, and formed of lumps and chunks of the subjacent rock, mixed up with the subsoil material. The adjoining diagram gives a section of a

soil such as is often met with over sandstone in a glaciated area, and in which all five formations are typically shown in their relative positions, but the same occur in every case where the undisturbed soil is dug into, and each stratum in the same relative position. Some may be wanting, as where the rock protrudes through, or where it is so near the surface that the soil rests directly on it, or where the turf and soil have been removed, leaving the subsoil bare. (Plates IV. and VI.)

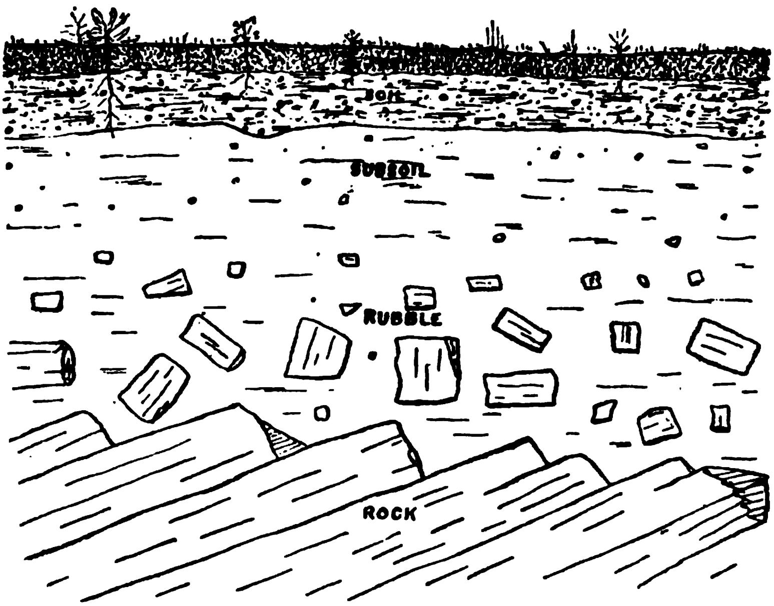


FIG. 5.

SECTION OF SOIL.

The subsoil is practically the material out of which the soil has been made—or at least the mineral part thereof—and consequently a study of the composition and nature of this ought to give valuable hints regarding the nature and treatment of the overlying soil.

The above is a description of the normal state of matters, but it must be pointed out that in arid regions there is no distinction

between soil and subsoil—at least, no very clear distinction—as, indeed, the whole surface may be just equal to subsoil. The absence of moisture has prevented the formation of the humus or organic part, though equally so the formation or accumulation of poisonous compounds in the under parts. It follows, therefore, that where water—*i.e.*, irrigation—only is needful to develop vegetation, the under layers are as fertile as the top part, and may be turned up if desired; whereas, in ordinary soils the subsoil must be very carefully dealt with. In connection with this, the case of a soil which is arid or unfertile from want of moisture only (as the Sahara) must not be confounded with those which are barren from excess of alkaline salts, like the "Bad Lands" of North America.

Depth.—There is a wonderful regularity in the depth of the soil all over the country, excluding only the "water-fed" flats. This depth varies from 3 inches to over a foot; that is, of course, reckoning only the "vegetable mould," or part which is darker in colour than the subsoil, and which is the stratum in which plants can develop their roots, and in which the ordinary acts of husbandry are performed. In France, Boussingault gives the soils as from 4 to 13 inches deep; less in Germany, according to Von Thaer; Russia's black loam is thin, according to Murchison; the soils of New England are not more than 6 inches thick; those of the western prairies are generally deeper—up to 18 inches sometimes—but sometimes no deeper than a plough furrow; in Australia from 4 inches to a foot is the rule from Geelong to the plains of Victoria, and on the country around Sydney; and on both the North and Middle Islands of New Zealand it is from 4 to 9 inches deep.* Of course, the difference between 4 inches and 12 inches is immense from a farming point of view, and will modify the systems pursued to the greatest extent. It is desirable that the soil should be at least as deep as a plough furrow—5 to 7 inches—but as much more as possible. Ordinary cultivation—three-horse ploughing, for instance—may be done to the depth of 12 inches, or even more if the land is suitable, so that it is obvious that on a shallow soil deep cultivation is at a discount. It is possible to deepen the "staple" of a thin soil, but it must be done very judiciously. Stirring the subsoil without bringing it up is a good plan, while a little of it

* Melvin: "On the Surface or Vegetable Soil," p. 133. *Trans. Edin. Geol. Soc.*, 1877.

brought up by the plough at each rotation is allowable, but it must not be overdone, as many farmers have found to their cost that it is disastrous to endeavour to increase the natural depth of a soil in too great a hurry. The infertility of the subsoil, and the poisonous unoxidized material it is likely to contain, make it desirable to allow it to remain where it is in a large number of cases.

Particles of Soil.—The size of the particles in a soil has much to do with its capabilities from a physical and chemical point of view, though, of course, these depend much on the proportionate presence of the "proximate constituents." A clay, of course, is made up of the smallest and finest particles, some, indeed, so fine that they are able to float in water for days before settling down, while other particles are as coarse as gravel or stones. Sandy soils may have 40 to 65 per cent. of their bulk made up of particles of from 1-1,000th to 1-400,000th of an inch in diameter, with the rest from 1-20th to 1-100th of an inch in diameter; while a clay soil may have 80 to 95 per cent. of its bulk composed of particles of the smaller size.

It is customary to look on sand and clay as the opposites of each other, but physically, the difference is largely due to the size of the particles alone. When the particles of sand are very fine it approaches clay in its properties as regards capillarity or water-holding power, and may be "cold and wet," and even plastic.

If the particles of the soil were all spherical in shape, and all of one size, the open spaces between would amount to 26 per cent. of the bulk; if these spaces were filled with smaller spheres the spaces would be reduced to 6·7 per cent. of the whole; and if the remaining spaces were filled with a still smaller set of spheres the space would be reduced to 1·7 per cent. On the other hand, where the particles are of irregular size they pack closer together and so reduce the spaces, as is the case in an ordinary soil, but irregular shape tends to increase the same. An average soil with the particles all about the same size has about 40 per cent. of interspace, but, as much of the material is itself porous—such as the organic matter, chalk, &c.—the amount of space which can be occupied by water (of saturation) is largely increased, so that some soils can hold 50 per cent. of their bulk as water, while others may hold under 30 per cent. The amount of water held by capillarity is, of course, a different matter, varying inversely as the size of the particles.

Capillarity.—This is the term used to describe the power which all bodies have of soaking up water or other liquors. The liquid, as it were, creeps up through the pores of the body, more or less according to the size of those pores ; higher where the pores are smaller, and conversely. Where the particles composing a given body—such as a clay soil—are small, the number of the pores or divisions is increased, so that in a strictly scientific sense such a soil is more porous than a sand or gravel one. In a common sense way, however, a clay is looked on as the reverse of porous, while sandy and gravelly ones are always described as "light and porous."

If glass tubes be filled with various different soils, and the lower ends of these set in water, it will be found that there is a very great difference between the samples as to the speed and extent of the rise of the water in these due to capillarity. This difference is mostly due, of course, to the relative sizes of the particles of each kind of soil. The following table illustrates how far the water rises in the case of several typical soils during the first 24 hours of trial :—

	Inches.		Inches.
Clayey soil ...	50	Peat	28
Humus	44	Sandy soil ...	22
Garden earth ...	40	Gypsum	20
Quartz sand ...	29	Chalky soil ...	17

This is the reason that clay land stands the drought best in summer ; the continual soaking of the water upwards being more effective in soil with some fine matter—such as clay or humus—in its composition than in an open, "porous" soil. On the other hand, for this very same reason, a clay soil is "wet and cold" : the extra capillary power in working the water upwards, and the greater difficulty excessive water has in percolating downwards tending to keep too much moisture near or on the top, during the winter especially, when evaporation is at its lowest. It is the capillary action of the water which not only largely supplies plants with the necessary moisture for their sustenance, but also largely supplies the mineral food. The soluble salts of the soil are in solution—or some of them are—and get carried up from the lower levels within reach of the roots in summer, and thus to a large extent is checked the leaching or washing out due to excessive rain or drainage. On the other hand, the majority of soil salts in

solution check the rate at which the water rises by capillarity—such as calcic carbonate, common salt, gypsum, potassic carbonate, nitrates of lime and soda, &c., as compared with pure water.

It is, indeed, the capillarity of a soil which largely prevents it from being leached so much as to become a barren sand, grit, or clay. The soluble salts are carried up as well as down, and actually may be carried up so much as to form an efflorescence on the surface of the clods in dry weather, and it is the frequency of the rainfall which prevents it from becoming more apparent. In many arid countries, however, this efflorescence is so great as to poison the surface and prevent the growth of vegetation. The same thing may be noticed on brick walls: various salts come out on the surface and form a whitish coating in dry weather, and which are returned to the interior by the next spell of wet weather, and this journey out and in of alkaline matter may go on indefinitely. It is, indeed, the constant elevation of plant food to the surface which enables grain plants to find sustenance.*

The more loose and "porous" a soil is, the less does capillarity act, and when looseness is brought about artificially in a soil it has the same effect. Thus ploughing retards the rate of evaporation from the unstirred portion below by making the layer on top more open and loose than before, while hoeing, scarifying, harrowing, and all other forms of surface cultivation have the same effect. This is the reason why, in a dry season, a continual stirring of the surface conserves the moisture, and thus helps the growth of the crop—apart from loosening of the soil for the easy passage of the roots and the entrance of the oxidizing air; and why arable crops sometimes succeed in a drought, while the adjoining pasture or other unstirred land is scorched up and the plants stunted.

Texture.—A soil may be loose and porous—using porous in the ordinary sense of having large pores, with an easy passage for water—or it may be dense and tenacious, as in the case of a clayey soil. This, of course, again depends on the proportions of sand, clay, and other constituents present, and as a rule follows the plan that where sand, or lime, or humus, or gravel are present in abundance there the texture will be loose, friable, and easily worked; while if clay predominates, or even exceeds 30 per cent. of the total composition, the converse will be the case, and the soil

* Shaler: "Origin and Nature of Soils." *United States Geol. Sur. Ann. Rep.*, June, 1891, p. 309.

will be hard and lumpy when dry, sticky when wet, and with little percolating power or ability to let water soak through. At the same time there are some open types of clay soils which have a tendency to be granular in texture, almost like a loamy or even a sandy soil, while under-draining improves this tendency to a great extent. Even stiff clay will shrink in a dry season, and draw together into cubical masses, thus facilitating the penetration of roots, and thorough aeration of the lower layers. Further, it is well known that lime-water has a flocculating effect on clayey material, and as the opening up of a clay soil by constant cultivation promotes the action of the water acidified by carbon dioxide on the lime in the soil, this granulating tendency is promoted thereby.*

Tenacity.—As tenacity means stickiness, it follows that with regard to a soil this depends on the proportion of clay that is present, and as clay is the most absorbent constituent, the tenacity of a soil is to a certain extent synonymous with the retentive power of the same for manurial matters. This absorbent and retentive power, however, depends also on the amount of humus or organic matter present, and, indeed, a soil with a large proportion of peat in its composition has the best filtering power—that is, is most absorbent and retentive of fertile ingredients. An addition of farm-yard manure to an ordinary soil has also this effect, while reducing the tenacity of the same. On sandy soils the increase of humus—as by a dressing of dung—increases the tenacity; conversely of clay.

The ease or difficulty of ploughing or cultivating any particular field depends on the tenacity of the soil to a very great extent. The draught of the plough is the best measure of this, tested by the dynamometer. A clay soil may require five times as much force applied to a plough as is required on a sandy soil, or, to give exact figures, the draught of the plough on sandy soil may be as low as 27 lbs. for every inch in depth of furrow, as against over 100 lbs. for the same on clay. This means, in practice, that on some "light" soils an ordinary furrow is easy work for one horse, while on some "heavy" soils it is heavy work for three horses. "Three-horse land" should, for this reason, be always in grass.

It was held by Schlœsing that clay owes its stickiness to the presence of a hydrated colloid body, which occurs to the extent of

* King: "The Soil," p. 76.

1·5 per cent. in it. This is coagulated by salts of lime, and the action of lime on a clay field is to cause flocculation or granulation of the particles by its action on the cementing material.

It is even stated by one writer* that the action of frost is to coagulate this colloid cement by removing the water. If this is so, the effect is exceedingly temporary, for the clay will work up into a plastic paste again immediately the thaw comes, while even to plough clay soil immediately after a thaw will spoil it. If untouched until the dry weather comes, it, of course, keeps its granular state for some time, till it gets wet and solid once more. The author is of opinion that it is more natural to look on the action of frost as purely physical: the expansion of the water by freezing splits a lump of clay up into granules, exactly in the same way as it does a lump of chalk; those granules are as plastic as ever as soon as the frost goes, but keep their shape and granular state for some time when dry or untouched. With lime there really is coagulation or "flocculation," and a soil is made permanently more granular than before.

Even if the effect of the liming is not permanent, it will, at any rate, last for many years. The Agricultural Holdings Act, 1901, fixes no limit of time to the claim for the unexhausted value of liming between an out-going and an in-coming tenant, but some farm agreements known to the author fix the period at five or six years, and some valuators allow seven years. This is, of course, for valuation purposes only, and to fix and limit the claim of the man who put the lime on, for the effect is much more lasting; the author, for instance, can see a decided effect on the crop, and feel a difference in the tenacity of the soil in the ploughing, on land where a heavy dressing of chalk-quicklime was put on more than 20 years ago.

Colour.—The colour of a soil has much to do with its fertility; not because of the colour merely, but because it at the same time is generally an indication of the temperature. Dark colours always absorb most heat from the sun's rays, and light colours or white the least. This means that dark red, brown, or even black soils will yield larger crops and have earlier harvests than those of light colours, where other things are equal. This is well exemplified in the black, loamy soils of the American prairies, the Tchornoi Zem of Russia, and other similar ones, where the growth is phenomenal,

* Warington: "Physical and Chemical Properties of Soils," p. 4.

being partly due to the black colour, as well as to the great fertility and warm sun. Practical farmers always prefer a dark red or brown soil in this country, because they have found from experience that the lighter-coloured soils are not so desirable. In the British Islands, however, the black soils are mostly peat, which is often too damp, and grows crops of a soft nature—*i.e.*, crops that become easily lodged or rotted (excepting only potatoes)—and, therefore, any benefits derived from the black colour are counterbalanced by these drawbacks. The principal colouring materials are humus (giving black or dark colour), various oxides of iron (giving brown, yellow, and red in various varieties and mixtures), and marl or limey material (giving grey or even white); and the comparative temperatures of soils will be found to vary much according to the colour due to these. Apart altogether from lithological character, moisture, or any other influence, the difference between black and white as two extremes in soils has been found to equal 14 deg. Fahr. in the temperature.

The following table illustrates this in the case of some actual soils under the same conditions as to exposure to the sun's heat, tested by the insertion of a thermometer. The component materials no doubt influence this to some extent, owing to variations in the specific heat and heat-absorbing power; but it is noteworthy that the blackish peat is highest and the whitish chalk lowest, with the soils of intermediate colours graduating between :—

	Deg. Fahr.
1. Moor peat	86·5
2. Humus	84
3. Sandy humus	83
4. Soil coloured by iron oxide	82·5
5. Humous clay	80·5
6. Humous loam	80
7. Loam	80
8. Clay	77
9. Sand	76·5
10. Chalk	73

It is said that some of the chalk soils in north Herts are not warm enough for the growth of stubble or catch crops.*

* Elsden: "Agricultural Geology of Herts," p. 148. *Trans. Herts Nat. Hist. Soc.*, June, 1883.

Temperature.—The temperature of the soil varies very considerably, and is influenced by a large number of factors besides that of colour alone. To begin with, the kind of soil has itself a great influence on the warmth of the same from heat derived from the sun, while the presence or absence of water has also a great effect. If the soil is perfectly dry, the amount of heat which will raise a given weight of water 10 deg. Fahr. will raise the same weight of humus 22·6 deg., of clay 44·58 deg., and of sand 52·38 deg.* As a further example of this fact another case may be cited: when the temperature of the air was at 90 deg. Fahr. the temperature of the soil at one inch below the surface was as follows† :—

	Deg. Fahr.
Quartz sand	126
Garden soil	114
Chalky soil	87

Under field conditions the soil is never quite dry, and as a proportion of the heat must therefore be first used up to warm or evaporate the water, the total result of the sun's rays on the soil is thus modified. As the sand, however, is the most easily warmed up, and holds the least moisture, we see why it is that a prolonged drought is most disastrous on a soil of this nature; though, for the very same reason where there is a sufficient supply of rain, crops grow most quickly and mature sooner. It is thus, again, that the removal of superfluous water by draining raises the average temperature of the soil. The heat which would otherwise be wasted in warming up and evaporating the excess of moisture is left free to act on the soil wholly and directly, so that so long as there is sufficient capillary and adhesive moisture left to supply the plants, the unrestricted heat is free to stimulate them correspondingly more. The difference in temperature of soils due to mere wetness and dryness is considerable. Schübler found that the average of 12 soils gave a temperature of 100·5 deg. Fahr. in the wet state, as against 112·5 deg. Fahr. in a dry state, showing a difference of 12 deg. Fahr. in favour of drainage. This one condition of warmth is sufficient to make the harvest 10 to 14 days earlier, and to help the ripening of plants or crops in districts where they would not naturally do so, but the difference between dampness *versus* dryness

* King: "The Soil," p. 225.

† Webb: "Advanced Agriculture," p. 16.

in its effect on temperature is not noticeable below 30 inches in depth.*

Schübler's figures are rather too high for ordinary soils, as in other experiments it was found that wet soil was at a temperature of 43·5 deg. Fahr. and the same dry at 49·5 deg.—a difference of 6 deg. Fahr.,—but either way these illustrate the benefits of draining.

But the difference in temperature due to *material* of soil has been found to be 7 deg. Fahr. in favour of sandy soil over that of a clay composition in August on the surface, and the difference extended to over 3 feet downwards, where it was 5 deg. Fahr. higher. Mineral matter, again, is a better conductor of heat than either humus, air, or water. The slope of the surface means a difference of 3 deg. on an angle of 18 deg. facing the sun over the temperature of the same soil on the level.† The angle of incidence of the sun's rays has, indeed, much to do with the amount of heat received by the soil, as it is the chief reason for the difference between the temperature of the tropics and the regions north or south. In our latitudes, land facing the south with a slope of about 30 deg. receives the most heat, though this slope is too steep for comfortable farm work. Again, a north slope has been found to be at least 3 deg. Fahr., on an angle of 30 deg., colder than a southern slope of the same, so that there is a considerable variation in the temperature of soils depending on the nature of the lithological composition, aspect, slope, moisture, &c. Even ordinary rolling affects the same: King found on eight farms in Wisconsin, with various soils, that the rolled ground was about 3 deg. Fahr. warmer on the average than the unrolled portion alongside, from observations taken from 1 to 4 p.m. in the spring-time,‡ and the difference has been as much as 10 deg. Fahr. in special cases.

Several more factors influence or modify soil temperature to some extent, but that of vegetation is the only one calling for further special comment. In summer-time the vegetation protects the soil from the sun's rays, and consequently the soil is cooler under grass or a growing crop than on bare fallow. In winter, however, a covering of vegetation protects it from the effects of cold to a considerable extent, the amelioration being sometimes equal to a difference of about 10 deg. Fahr. on turf. Ploughmen

---

* Stockbridge: "Rocks and Soils," p. 169.
† King: "The Soil," p. 228.
‡ Ibid., p. 232.

know of this difference practically, for often after the advent of frost in winter-time the stubble ground or other bare fields are sealed up by freezing, while on grass land the plough can still be kept going for days thereafter. Conversely, when the thaw comes, the ploughs can get to work soonest on the bare land, while it may take a week for the frost to "come out" of the grass land.

Even an application of farm-yard manure on the surface will act as a "mulch" and protect the soil from both the heat of summer and the cold of winter. If the dung is ploughed in, it at first warms the soil, from the fermentive changes in its composition generating heat, as in a dung-clamp, but after it has become more or less changed into humus it actually reduces the temperature, owing to the increased power of holding moisture.* From 10 to 20 tons of dung per acre thus ploughed in raised the temperature in the first few days from 2 deg. to over 3 deg. Fahr., but by the expiry of 25 days the temperature became reduced to nearly 1 deg. Fahr. under that of untreated soil, owing to the manure holding more water.

The influence of the sun's heat penetrates to a considerable depth into the ground, and the seasonal influence on an average over many districts may be tabulated thus for midsummer and midwinter † :—

		Midsummer.	Midwinter.
On surface	...	July	January
3 feet deep	...	August	February
12 ,,	...	October	April
24 ,,	...	December	June

That is to say, at a depth of 24 feet the seasonal rise and fall of temperature is reversed, as it takes six months for the surface heat or cold to penetrate to that depth. At and over 90 feet the variations of winter and summer are wholly insensible; in some cases no change having been detected at 50 feet. In practice, this means that at a depth of a few feet in the soil it is always cooler in summer and warmer in winter than it is on the surface.

To put the matter shortly and systematically, the temperature of the soil is influenced in the following ways :—

Sandy or gravelly soils absorb heat more rapidly and retain

* Fream : "Soils and their Properties," p. 83.

† Page : "Geology," p. 36.

the heat longer than loam or clay do, and are therefore reckoned warmer and "earlier" soils.

Dark-coloured soils absorb more heat than light-coloured ones, so, therefore, peaty and humous soils are warmer and earlier than whitish, chalky soils.

The more moisture in a soil the more of the sun's heat is used in warming up and evaporating this water, so that the temperature of the soil itself will be raised more slowly, and it will cool proportionately more quickly ; therefore, damp soils are cold and "late."

The aspect of a soil—as facing south against facing north—will much affect the amount of heat received from the sun, taking either any day of any season or the whole year.

The inclination of any field will influence the amount of heat received from the sun ; a plain will receive less than a sloping field inclined to the south, and a slope to the north least of all.

A covering of vegetation retards ingress and egress of heat, and conversely a bare stubble or fallow is more quickly influenced both ways. Land under a forest may never feel the effects of frost at all, but will also never have much rise of temperature in summer.

CHAPTER V.

WATER SUPPLY.

THE water supply of a district and of the individual farms therein is a matter of vital importance to all connected with the land. It, of course, depends mostly on the rainfall, though, as was shown above, this largely depends eventually on the geological formation, at least in the British Islands; but to come down to detail it is desirable to explain how the existence and nature of springs, wells, stretches of naturally wet land and of dry land, the composition of the water itself, and similar points, are all due to and explainable by the geological formations beneath.

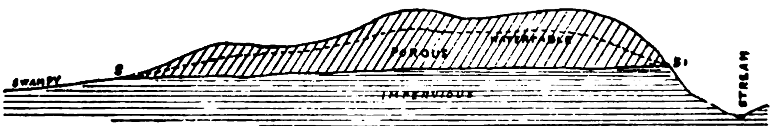


FIG. 6.

WATER-TABLE AND OCCURRENCE OF SPRINGS.

It is calculated that in round figures about one-third of the rainfall is evaporated into the air again, one-third flows off the land immediately into the ditches, brooks, and rivers, and the remaining third sinks into the ground to supply the springs and generally to form the "ground water." Of course, the proportions vary greatly according to the district, a larger percentage, for instance, running off the surface where the formations are argillaceous, or hard and compact, while on the chalk or sandy strata the larger proportion immediately sinks, to be afterwards restored to the surface in springs or wells at a lower level.

The arrangement and distribution of the ground water will be best understood from the adjoining diagram (Fig. 6) which represents the structure of a hill partly composed of porous material—such as is of a sandy or gravelly nature—and partly of compact material like clay or hard rock; the section being taken to represent several miles of country.

When rain falls on the surface of a fairly porous formation, part of it immediately begins to sink into the same, or perhaps it would be more correct to say it soaks into it. The downward soakage continues until the water meets some impermeable strata, such as a bed of clay or a fissureless rock, when it begins to accumulate until it fills up all the spaces, pores, crevices, &c., between the particles composing the porous bed. The top surface of this bed of water accumulating in the ground is called the "water-table," and if the rain continues long enough and plentifully enough it rises nearer and nearer to the surface, until, on low-lying ground, it may rise above the same and form a swamp, or even a lake.

But while the water is accumulating in the ground in the manner indicated, there is at the same time the force of gravity acting on it and giving it that uncontrollable tendency to run downhill which we always see manifested in all liquids when left to themselves. Besides this—or as a feature of this—the water in the upper part of a high-lying piece of ground is pressing on that below it, and as it cannot get downwards it oozes out sideways, and thus we have the formation of springs; and these show themselves either as actually running rivulets starting all along the outcrop (at S and S^1) or as spots of land in an extra damp or water-logged condition.

The water continues to percolate downwards and outwards until the water-table descends to about the level of the springs, and these will then give up flowing—as may happen in a drought—while the water-table rises again when rain falls to make up the supply.

The existence of the water-table is shown in the case of a well. It must be dug down below the level of this, and the water will rise in it and stand at this line. If the strata is of tenacious texture the well may be pumped dry, but will fill up again from a fresh supply percolating into it; while if the strata is sand or gravel, the water will flow in easily and fill up to the level quickly as long as there is a store of water to draw upon.

The upper surface of the water-table follows, in a general way,

the undulations of the ground surface, but is furthest below that on the elevated parts, and approaches nearest it in the hollows or valleys and near the streams.

It is, however, subject to endless modifications according to the strains of clay, sand, gravel, or rock forming the ground at any given field, and this is why a well sunk at one part may never contain any water, while one a few yards further away may have a plentiful supply—a bed of sand or gravel forming a reservoir as it were in one case, with impervious clay intervening in the other.

It will explain a good many of the phenomena connected with ground water, as regards water supply, pipe-tile drainage, and the nutrition of plants, if we enumerate simply the ordinary physical laws which govern water in common with every other liquid in this wet country.

By virtue of the action of gravity, water percolates downwards into the soil; owing to the action of adhesion a certain proportion sticks to the surface of the particles of the soil or subsoil; the porosity of the particles allows of the absorption of some into the actual mass of matter—*i.e.*, in between the molecules—or at least the component minerals, as water is absorbed by a brick; while the law of capillarity enables water which has already descended to the depths to soak upwards again to supply that which has been re-absorbed into the air from the action of evaporation.

Lastly, but not least in importance, is the friction of the water against the particles of soil in passing through the ground—comparatively slight where the channels are wide and open, as in chalk or gravel, and overwhelming where the particles are fine, as in clay, through which water can with difficulty pass at all. The difference of the rate of percolation between the two extremes may be shown in figures: if the percolating power of clay be taken as 1, then fissured chalk will be 600, with other materials intermediate. It is for this reason that clay districts are deficient in good springs and in filtering power,* so that water has either to be brought from a distance, wells sunk in the beds of sand or gravel found here and there among the clay, or else ponds made to collect the surface-water.

The slowness of percolation of water downwards and sideways in keeping up a supply to wells, springs, and rivers is well exemplified in the case of the Hertfordshire chalk hills, where the

* Cooley: "Physical Geology," p 248.

underground water takes 16 months to travel from the central area to its outlet in the perennial springs which feed the River Lea; while on the Chilterns and the North Downs it takes four months for the rainfall to penetrate downwards to the water-table, a depth of 600 feet in some parts; so that in the former case the springs of the Lea would run for 16 months after a drought set in, and in the latter the winter rainfall raises the wells to their highest level in spring and early summer, and the droughts of summer are most felt in autumn and early winter.*

The amount of water which can be held per cubic foot in the different formations—both as regards that held in the pores and crevices under the line of supersaturation or water-table ("water of saturation") and that held by capillary action ("water of imbibition")—is of importance and interest in regard to the water supply, drainage, and the supply of moisture to the roots of plants. The following tables give some typical cases of this, exemplifying the variations we meet with in different formations :—

SATURATION.	Volume per cent.
Chalk	32·0
Lower Greensand, very coarse	34·9
Do. coarse and ferruginous	40·3
Garden soil	41·6
Woolwich Sands, fine grained, quartzose	41·6
Thanet Sands, fine, slightly clayey	44·8
Upper Greensand, slightly clayey, quartzose ...	48·0

IMBIBITION.	Volume per cent.
Carb. Limestone	0·7
Millstone Grit	0·9
Old Red Flagstone	1·4
Magnesian Conglomerate	5·3
Old Red Sandstone	11.6
Inf. Oolite Limestone...	12·1
Old Red Conglomerate	13·5
Magnesian Limestone	16·3
Inf. Oolite Sandstone...	23·9†

The percentage of water which is held by the action of capillarity in the body of the soil or surface accumulations also varies very

* Prestwich : "Geology," Vol. I., p. 165.
† Ibid., p. 157.

considerably according to the nature of the same, as is exemplified in the following table :—

	Volume per cent.
Sandy loam	17·6
Sandy clay loam	26·5
Cláy loam	28·8
Clay	34·0

That is to say, that the finer the particles of soil, or the more clay or humus present, the larger the percentage of water retained. This explains in practice the ordinary phenomenon of crops succeeding in a dry season much better on a clayey or humous soil than on a sandy or porous one, simply because there is naturally more water held in the former which the roots can get than in the latter, though if sufficient rain falls during the period of growth this difference disappears.

But even in the case of the same soil under different conditions the amount of water retained varies. Thus, keeping the surface of the soil stirred to the depth of half-an-inch by hoeing increases the water-content of the first 12 inches to a very appreciable degree, and the deeper the tillage up to four inches the greater is the increase of water-content, though beyond this the increase diminishes as the depth increases. Mulching the soil, again—that is, covering with a layer of dung, or straw, or vegetable refuse—exerts a great influence in retaining the moisture and increasing the water-content of the soil.* Not only is this so, but ordinary ploughing, if done in autumn, also increases the amount of water in the top layers of soil.† This appears to be due partly to the fact that the loosened soil allows of the downward percolation of water more readily, so that a greater store is accumulated, while the furrow-slice of moved soil acts as a sort of mulch, preventing excessive evaporation. There is more evaporation when a crust or cake is formed on the surface, so that the breaking up of this by hoeing or other cultivation keeps a greater percentage of water near the roots of the plants, as is also the case where harrowing leaves a good covering of loose crumbs.‡

Rolling the land at first increases the water-content of the surface portion which has been subjected to consolidation, but the

* Fream : "Soils and their Properties," p. 81.

† King : "The Soil," p. 187.

‡ Ibid., p. 192.

whole ground soon comes to contain less, on account of the increased rate of evaporation. This is not merely due to the more rapid capillary upward flow of water through the firmed soil, but partly also to the increased wind velocity on a smooth surface, which may exceed that on a rough surface to the extent of 70 per cent., so that thus the absorbent power of the air in touch with the soil is increased correspondingly.* If the rolling is done on a dry surface, the action is to pulverize the crust and lumps, and thus make them really loose and open, but otherwise, following the roller with a light harrow would conserve the moisture in a dry season or region.

A great deal, of course, depends on the nature of the soil and the climate, and many differences met with in the cultural practices of different districts are explained on the principle simply of conservation of soil moisture or the converse. There is more evaporation from soil laid up in ridges than on the flat: turnips and other roots, therefore, are grown on the flat in the south of England, where the rainfall is the lowest, while they are ridged up high in wetter districts. Deep cultivation is more likely to do good, again, in a dry district than a wet one, because it not only prevents over-evaporation, but helps the downflow of rain-water and encourages the descent of roots to a depth sufficient to ensure a supply of ground water to them. On the other hand, in a wet district the conservation of moisture is no object, while the easier downflow of water tends to wash out fertile ingredients. The experience of a generation of farmers of a countryside in these matters will generally show what is best to do in this respect.

Draining.—Some of these facts explain the phenomena connected with the draining of land. To begin with, however, the action of drains is very often erroneously stated in many text-books. It is, for instance, pointed out that these lower the "water-table." Now in 99 cases out of every 100 the water-table is at a very much greater depth than the three or four feet adopted in draining, as is shown by the fact that the water in wells is seldom so near the surface as this, but generally at a greater depth. Indeed, it is only in the case of gravelly or sandy flats near a river, or the middle of a valley, or where a spring comes out, that an ordinary drain ever reaches the water-table at all.

To understand its action it is necessary to realise, however, that while complete saturation—the "supersaturation" of some books

* King: "The Soil," p. 202.

—exists only up to the line at which water would stand in a well, there is at the same time a lesser degree of saturation above that, and diminishing upwards till it reaches the surface, where there may be perfect dryness. Examination has shown that for every foot we go down we have an increasing proportion of water until we reach the point or line of thorough water-loggedness. This intermediate state is partly due to the percolating process of the water taking some time—more in a tenacious clay and less in an open gravel—and which is being constantly modified or varied by every shower which falls on the surface or by every spell of dry weather; and partly due to the capillary attraction of the particles of the formations near the surface by which the water tends to continually soak upwards from the store below whenever the upper layers become dryer by evaporation. There is thus a constant soakage or an actual flow of water in the ground downwards, sideways, or upwards, constantly varying according to the weather and the nature of the beds below the surface.

The varying relative proportions of water in ordinary surface formations as we go from the surface downwards to the water-table are shown by the following figures (Fig. 7) :—

1st section	...	...	16	per cent.	of water.
2nd "	...	...	19	"	"
3rd "	...	...	22	"	"
4th "	...	...	28	"	"
5th "	...	...	40	"	"

Furthermore, it is necessary to realise that the air in the soil greatly influences the flow of the water. When this latter descends either from natural or artificial drainage, the spaces it leaves are, of course, filled with air, and when the weather remains dry for some time the ground may be aerated for some distance down. When rain falls on the surface it fills up the interstices near the top, literally pasting up all the holes of egress, and thus the air becomes imprisoned and prevents the water from descending. It is only as the result of slow, gradual soakage—at least in the stiffer soils—and following on the gradual escape of the air, that the water gets down into the lower parts. This is the reason why a deluge of water during a thunderstorm in summer after a spell of fine weather does not wet the soil at all, but only the surface: the first few drops paste up the pores; the air cannot get up and the water cannot get down, and so it runs off the surface into the

hollows and ditches. The soil will often "sing" or "sizzle" after a downpour, the sound being caused by the air escaping through the wet layer.

We are now in a better position to understand the action of a drain or open ditch in freeing the surface beds of superfluous moisture. A subsoil that is close in texture may allow the rain-water to percolate down so slowly that where there is an ordinary amount of rainfall it may keep the top part so wet while the rain lasts as to do as much harm as if it were permanently water-logged, a state of matters further accentuated by the fact that capillarity is strongest in such material. Even if the water-loggedness only holds in winter, when the rainfall is heaviest, the "souring" of the land—*i.e.*, the development of poisonous organic acids such as humic, ulmic, &c.—or the development of sulphuretted hydrogen or

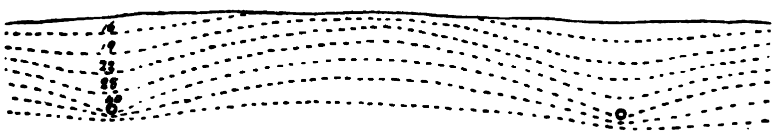


Fig. 7.

Diagram of Drain Action.

carburetted hydrogen gases, is detrimental to vegetation in the succeeding summer, long after the superfluous water has sunk below the reach of the roots. Now, when a pipe-tile drain is put in at a depth of, say, three feet, this superfluous moisture begins immediately to leak into it all round; the water next to that follows on, finding the pressure relieved sideways, and eventually a line drawn through the ground between the drains at the part where the dampness is of equal intensity would rise between the drains (as shown in the diagram, Fig. 7) in the same way and for the same reason as the line of the water-table follows the inequalities of the surface. The pipe drain is, in fact, bringing a piece of the surface down into the ground; the ground between two adjacent drains is equivalent to a hill, and the water oozes

into the pipes in exactly the same way as a spring flows out at the bottom edge of a hill.

But further, the lessening of the pressure at the pipe acts downwards as well, and the strata immediately below the drains has the amount of water held in it lessened. Thus the earth all round a pipe is acted on, and this is what is meant by a farmer when he says that a drain "draws" the water to it. But this "drawing" power strictly depends on the nature of the beds: it reaches furthest and quickest in open, gravelly or sandy soils, and least in clays—indeed, the example above given of chalk *versus* clay shows that it may in the case of open gravel be 600 times greater than with a dense clay formation.

The knowledge of how to apply these facts practically in farming has been bought by costly experience. Thousands upon thousands of pounds have been wasted on putting in drains too deep and too wide apart on the stiffer formations. While drains may be four and even five feet deep and 50 yards apart on gravelly soils because the water will "draw"—that is, percolate—that distance, it has been found that 30 inches deep and four yards apart is quite little enough on some clay formations. The water soaks so slowly through these that unless the drains are shallow and close together the ridge of land between is never dried in our climate, where there is so much rainfall. The regulations in force by some of the public drainage authorities as to depth are even yet absurd for stiff soils. The author's farm, for instance, was all drained originally four feet deep, and has had to be re-drained 30 inches deep to do any good, on account of the stiff, plastic nature of the London Clay.

A good result of the presence of a drain which may be mentioned in connection with this is the fact that it acts as an outlet for the air. It was pointed out above that when a soil was dry and full of air the first rain could not get down until the air worked out. Now the imprisoned air can get egress into the drain, so that, thus, drained soil lets the water down more quickly.

Composition of Water.—There is a very great difference between the composition of samples of water from different parts of the country. As this difference has a very great effect on the live stock that drink the water, and is due directly to the nature of the underlying strata, it is desirable to discuss the subject here. The composition of the water also affects the women and children

of a district, but seldom the men, for the reason that in most districts men never quench their thirst with such a common liquid as water.

Pure water is absolutely unknown in nature, and is only procured by the chemist as the result of distillation. Even water which is pure to the eye, and may have been filtered, may possibly contain a large amount of mineral salts in solution. This is not an objection so long as these are non-poisonous, as, indeed, they are absolutely necessary for the building up of bone and gristle in the animal economy—the want of lime in the water causing rickets, as Loch Katrine water did to the Glasgow children until lime was artificially added.

Very few of our ditches, streams, and rivers are even visibly pure at any time—*i.e.*, if a glassful is allowed to settle some solid sediment will be deposited—while in flood time they are, of course, muddy and turbid, with, in addition, a large quantity of matter in solution. This turbidity, however, is not an objection so long as it is not due to one or other of two causes, *viz.*, the presence of deleterious organic matter containing disease germs as the result of a mingling with sewage, or the presence of poisonous salts such as we often meet with in the waste water from mines. The former is not a matter falling within the scope of a geological enquiry, and, therefore, may be left to writers on sanitation—more especially as it is an artificial and controllable state of matters—and so may be dismissed here. The latter, however, is a matter of extreme concern to stock-owners whose animals graze on fields bordering on streams which drain the mines in a mineral country, and will, therefore, be gone into a little more fully.

Rain in falling through the air absorbs any impurities floating in the same—if not of a solid nature then carbon dioxide, oxygen and ammonia at least. Immediately it begins to percolate downwards into the ground it tends to dissolve out some of the salts of the alkaline earths—of lime and magnesia principally—so that the water becomes more or less "hard" according to the strata through which it has soaked. The substances carried in solution in river water are* :—

Silica.
Alumina.
Carbonates of lime, magnesia, soda, iron, and ammonia.
Sulphates of lime, magnesia, soda and potash.

* Geikie (J.): "Geology," p. 29.

Chlorides of calcium, magnesium, sodium, and potassium.
Nitrates and nitrites.
Peroxides of iron and magnesia.
Silicate of potash.
Phosphates.
Organic matter.

It is estimated that the Thames at Kingston carries down daily in invisible solution 1,500 tons, of which 1,000 is carbonate of lime and 240 sulphate of lime.* This superabundance of lime is, of course, due to the prevalence of limestone formations within the drainage area of this river, but each river -- indeed, each ditch—would, on analysis, be found to have its own proportion of solid material of various kinds according to the land or district through which it flows.

It is, indeed, from the contained solid matter—visible or invisible—that all sedimentary strata have been formed (with several exceptions) in bygone ages, or are being formed off the mouths of rivers or shores of continents now, so that an immeasurable quantity of material must have been carried down one time and another.

Soft water flows from hard rocks of upland districts of igneous rocks. Many streams average only 5 in 100,000 parts of water, while the Mountain Limestone regions give streams with as much as 17 in 100,000 parts.† The Dee only yields 3·12 parts and the Thames as much as 27·2 parts of soluble salts in 100,000 of water.‡

No substance is absolutely insoluble; the least soluble is pure clay or silicate of alumina, and yet this will dissolve at the rate of 1 part in 200,000 parts of water.§

Limestone will dissolve at the rate of 1 in 1,000 parts of pure water, and much more when carbonic dioxide gas is present. Gypsum dissolves 1 in 400, and thus in nature there is generally either of these two salts of lime present in water, producing the phenomenon known as "hardness"—the former yielding "temporary" or removable hardness, and the latter being the permanent form.

When granite or mica-slate abounds, potash and soda, and even magnesia, may be expected in notable quantities; while in limestone districts the waters are generally charged with lime.|| On

* Young: "Physical Geography," p. 109.
† Geikie (J.): "Geology," p. 29.
‡ Prestwich: "Geology," Vol. I., p. 106.
§ Stockbridge: "Rocks and Soils," p. 103.
|| Johnstone: "Agricultural Chemistry," p. 222.

the other hand, the streams in the Millstone Grit regions, for instance, are so poor in salts that few or no aquatic plants grow in the same.

In the ordinary drainage water of fields where manures, more or less soluble, have been applied on the surface, and the land has been subjected to cultivation, the Rothamsted experiments have shown that carbonate of lime, nitrates of lime and soda, chlorides of lime and soda, and sulphates of lime and soda occur in more or less appreciable quantities ; cultivation and its accessories, indeed, going to help to swell the volume of material which is found in the streams draining a district.

The drainage water from mines must be specially noticed, for it often has a considerable influence on the farming of the neighbourhood. The water from mines must, of course, be discharged somewhere, and though at its origin it may be led some distance in an artificial ditch, and thus be under control, yet that cutting must discharge into the natural streams of the district somewhere, and to which the live-stock of the district have access. Now, the drainage water from workings of any sort must always be muddy and turbid, and live-stock may refuse to drink it, and so run no risk, while if the muddiness be really only earthy or clayey matter there is no great danger ; but as mines are dug for the working of minerals or ores it follows that the waters from such are liable to be impregnated with salts in solution or mineral matter in suspension, which are deleterious to animal life. Examples will best illustrate this. The author knows of a sheep-farm in the Isle of Man on which is situated a lead mine : the water flowing from this is so polluted with lead, or salts of this metal, that the larger portion of the sheep-stock have died from time to time from lead poisoning, so much so that though 1,200 acres were held at a nominal rent the tenant had to give it up on account of the excessive death rate. In another case, in Nithsdale, the drainage from a coalpit caused the cattle which drank of it to be affected with diarrhœa—a proportion of them scouring to death—and, as a result, the stream had to be fenced in for nearly a mile until where it joined the volume of water in the River Nith.

Instances of a similar nature could be multiplied indefinitely, as, indeed, every district which is rich in any mineral is sure to have some of its water supply influenced by the same, the influence being for evil in most cases. Of course, as all districts in this country, not derelict, have been peopled with farming men for generations, the evils of any locality in this matter are known to

the inhabitants thereof, and arranged for accordingly; but a new-comer is likely to have to buy this knowledge at a big price unless he has some smattering of geology to guide him in avoiding "rocks" of this sort. As new mines of all kinds are being constantly opened up, however, the farmer on whose land this takes place may suddenly wake up to find that his water supply is being ruined, either by the discharge of poisonous water into it or the drying up of his wells from underground workings.

There is no doubt that much of the greatness of Great Britain is largely due to the amount of mineral wealth in her geological formations, but, unfortunately, miners of all kinds are particularly uncomfortable neighbours for farmers to have—excepting perhaps Cornishmen and some Welshmen,—and as this is a phase of geology not touched on in any text book known to the writer, it is all the more necessary to emphasise the fact that a farmer situated in any district rich in "mineral," and where miners with Saxon blood predominating in their veins form a large proportion of the population, is likely to have a hot time of it and to welcome a boycott for a change.

Not only does water take up material from the rocks or ores it comes into contact with, but even in soaking through the ordinary soil or surface formation there is a great amount of soluble salts taken up. At Rothamsted a set of experiments have long been carried out to test the amount of nitrates and chlorides thus "washed out" of the soil in ordinary drainage. Drain gauges have been constructed containing a space of 1-1,000th of an acre (6 feet by 7 feet 3·12 inches), enclosing unmoved soil of three different depths—20 inches, 40 inches, and 60 inches—and the rain-water percolating down through these has been carefully collected, measured, and analyzed. Over a period of 22 years the annual loss of nitric acid in the drain-water at 20 inches, 40 inches, and 60 inches deep has averaged respectively equivalent to 221, 197, and 216 lbs. of nitrate of soda per acre.

This, of course, refers to ordinary unmanured and uncropped soil, but on cultivated and manured soil there is a great deal more waste, at any rate for some time after the application of a dressing of manure. Indeed, often after a coat of farm-yard manure has been put on, the ordinary land drains can be seen to discharge dark-coloured water—especially on a clay soil with little filtering power—and thus for a time such water is undrinkable, until it returns to its normal salinity.

CHAPTER VI.

FORMATIONS AND FARMING.—I.

One of the great outstanding facts of Agricultural Geology is the circumstance that every rock formation has a soil peculiar to itself, and wherever rocks throughout the world have similar lithological characters the soils derived from such will be similar, and with a corresponding influence on the farming thereof—provided that no disturbing agencies have been at work, and the materials have been allowed to accumulate *in situ*. In this chapter an attempt will be made to describe the typical soil and farming characteristics of each of the formations of the British Islands, as far as the author can do so, though a certain amount of difficulty has been experienced in classifying the same for this purpose. The formations recognised by the Geological Survey have been taken as the basis of work, because each is represented on the Survey Maps by a special colour; and these maps must be used—both as regards the "solid" and the "drift" formations—by every-one desiring an intimate acquaintance with any district as regards its farming or otherwise. It is necessary to point out, however, that some formations of great importance geologically are insignificant agriculturally, and conversely, so that some slight deviation from the Survey list is necessary. An example of this occurs in the case of the Chalk: the Upper Chalk, Lower Chalk, Chalk Marl, and Chloritic Marl are all represented by the one green colour and the one letter (h^5) on the Survey Maps; yet the soils and farming of each is very different from that of the others—so different, indeed, that the fact is known to examiners, and questions have been set on the point at examinations in Agriculture on many different occasions.* In the recent re-issue of these maps there is very little improvement in this respect; the one colour represents at least three of the chalk formations without the boundaries of each being defined, and when it is pointed out that one of these yields good farming land and another yields the reverse, it will be seen that the Survey Maps of the chalk deposits are of little use to farmers.

---

* S. & A. Dept., Subject XXIV.; R. A. S. E Scholarships; &c., &c.

As the greater part of all soils is composed of the débris of less than a dozen minerals, and as there are only some eight classes of soils recognised in ordinary classification or even in practical farming, it may seem at first sight a stretch of the imagination to suppose that each of several scores of formations can have a specific soil of its own. A closer acquaintance with the circumstances, however, reveals the fact that there is often some secondary mineral present—such as the glauconite of the Greensand, or the pyrite of shales and subsoils—not to mention the zeolites believed by many to exist in all rich or heavily manured soils—which materially affect the fertility and general farming qualities of the same. Besides, there are many things influencing farming over and above the nature of a given soil, and which are dependent on the geological structure, as indicated in the previous chapter, and which will now be gone into more fully *seriatim.*

It does not matter much for our purpose which end of the scale we begin at, but it is perhaps a little more convenient to take the most ancient and deep-seated Crystalline deposits first, and then pass on to the Sedimentary. A tabular statement is given in the Appendix of these sedimentary formations, and their grouping into Periods, Epochs, and Series, so that we now here take them up in the order there indicated.

A.—*CRYSTALLINE OR IGNEOUS.*

Granite.—In a book of this nature it would be out of place to introduce the controversies of geologists on many subjects ; on this one—the origin and age of granite—it must suffice to say that there is no universally-accepted conclusion. It is enough for us, therefore, to plunge at once into the question of the effect the existence of the same has on the landscape and farming of the districts where it exists. To say that it is one of the hardest rocks —resisting erosion as much as any of the others known to the poets under the general name of "adamant"*—is to say that the country where it exists will be one of rugged and grand scenery, but an awful place to farm in. If we give a list of some of the most important granite regions, it will be simply naming some of the most mountainous and rugged. In our own Islands the most extensive "massif" of this rock is the Dublin and Wicklow

* "To the poets granite is the symbol of solidity and hardness." Risler : "Geologie Agricole," Tome I., p. 29.

Mountains with the adjoining part of County Carlow, 70 miles long and 7 to 17 broad. The next most important area is Dartmoor, while in Scotland the Aberdeen and Peterhead districts are famous for their granite quarries. Some of the Highland "Bens," again, are simply huge nubs of granite—such as Ben Nevis, Ben Cruachan, Ben Macdhui and Cairn-Gorm—while the lesser elevations are no less important: Goatfell, in Arran; Cairnsmuir of Fleet and Criffel, in Galloway—where "Mother Granite sticks her bleaching ribs through the heather." (Plate III.) Every occurrence of this rock need not be named, as a look at a geological map will reveal by its red spots the districts where it is to be found. It occurs as either "bosses" or mountain ranges, the fit habitat of sheep and cattle only—indeed, of sheep only in many places. In the glaciated regions it is, of course, prolific of boulders, thus adding to the ruggedness of the surface; but even in non-glaciated areas the frost-split chunks and slabs may be plentiful, as at Trewainton and Tredinney Hill, near Land's End, where the ground is covered with granite blocks, with heather, gorse, and fern growing between.

It cannot be said that the soil of itself is poor in the elements of fertility, as it contains at least potash, but often it is so situated as to prevent the accumulation of a typical variety, while the clayey nature of the insoluble parts militates against its value from a physical point of view, apart from the general ruggedness of a granite area. The soil is essentially a clay from the decomposition of the felspar contained, but as this is accompanied by corresponding quantities of silica and mica, it might be described as a gritty clay with a soapy feeling.

In the actual weathering it often happens that the silica is left behind and the mica completely dissolved out along with the felspar in the gentle washing and solution by rain, and consequently a deposit of pure pipe-clay, china clay, or "kaolin" is the result. This happens in some deposits from Dartmoor, but as a rule it is simply a yellow clay—mixed with "impurities"—that we meet with.

In the granite districts of Cornwall and Devon we meet with the most typical examples of another form of granite soil with different farming characteristics. These granite or "growan" (gravel) soils are classed as one of the four specific kinds to be found in Cornwall.* The "growan" form of granite soil is met

* "Farming of Cornwall": *R. A. S. E. Journal*, 1846, p. 404.

with in regions of little elevation, where the dissolving power of the water or the actual rainwash has been reduced in effectiveness on a more or less level surface, and such is, indeed, formed largely of disintegrated but undissolved fragments of granite, having, physically, characters varying from a brown loam to a brash or rough angular gravel.

The fertility depends very much on the elevation and exposure. On the hillsides the decomposition above described has taken place, and the alkalies being removed, the residue is invariably barren and nothing left but siliceous sand and gravel, as on the heathy and mossy waste of Dartmoor, the poorness of which, however, is largely due to it being high-lying and therefore exposed.* The same phenomena is met with in Argyllshire. In Glen Etive decomposed granite makes very poor soil, while in Sunart the same material gives very good pasture, and, when cultivated, remunerative crops †—elevation and exposure being a prime cause of the difference.

Iron in these "growan" soils helps them very much, but the associated schorl—a hydrated silicate of alumina and iron, with some boracic acid—if in excess lowers their fertility and farming value, as exemplified in the St. Austell and Luxullian granite in Cornwall.‡ On the other hand, it has been suggested that it is the absence of the mica in this variety of granite which is the cause of this inferiority.§ Where the washings collect in the hollows the soil is a stiff clay, with a yellow subsoil and dark-coloured top soil. On the granite area at Land's End the soil is good, because, the elevation being less, the whole materials of the original granite have been retained. The same formation, again, composes the Scilly Islands, the soil being of the "growan" variety—as also in the Channel Islands—black peat and granite particles mixed, and forming the basis of the early market gardening which has been so greatly developed within our own times, the low elevations and the equable climate being prime factors in producing this result. The red Cornish wheat suited this soil very well in olden times, yielding 40 to 50 bushels per acre

---

* "The rich granite soil on the west of Penzance has all its productive powers nullified on the high lands of Bodmin-moor and Dartmoor."—*R.A.S.E. Journal*, 1850, p. 5.

† *Trans. H. A. S. S.*, 1878, p. 9.

‡ De la Beche: *R. A. S. E. Journal*, 1842, p. 33.

§ *R. A. S. E. Journal*, 1856, p. 463.

near Land's End.* Granite areas are much improved by planting, especially with larch in northern districts, and other pine woods elsewhere.

Syenite.—Geologists are not unanimous as to what is the composition of a standard syenite rock. The original "syenite" of Syene in Upper Egypt, mentioned by Pliny, and already referred to, is simply a granite in which the mica is replaced by hornblende and containing quartz, while modern geologists tend to restrict the term to a compound of felspar and hornblende, and without any quartz at all.

Anyhow, the chemical compounds in its component minerals are rich in potash, soda, lime, and iron. In the words of Risler † : "It forms a clay, more or less ferruginous, of ochrey colour, and ordinarily mixed with fragments of hornblende, which contain a little lime, and consequently is more fertile than the soils derived from the pure granite." This, however, is not saying much, for when it is mentioned that Ailsa Craig—that solitary hump of rock rising up in the Firth of Clyde off the Ayrshire coast, and, on account of being midway between Scotland and Ireland, known as "Paddy's Milestone" because it was passed by the Irish harvest-men when coming to Scotland in the old days before the invention of the string-binder had ruined agriculture—is a boss of syenite, the reader will know that the farming on this sort of formation is not of a very advanced arable type.

Its occurrence in the British Islands is very limited, but some others of the more noted eruptions of the same may be mentioned: the Cuchullin Hills in Skye, Markfield and Grooby in Leicestershire, part of the Malverns, and in the Channel Islands. Abroad, the central axis of the Vosges is a good example, and as these are all more or less of a rugged character, the farming is practically the same as on the granite.

Mica-Schist.—Formed of quartz and mica in alternate layers; it crumbles down with comparative ease, and gives a soft, friable, deep layer of rich soil. On the Breadalbane chain of hills (Ben Lawers) this is exemplified by the extensive flora of Alpine and Scandinavian character, rich and well-developed in contrast to the poor appearance on the granite of Braemar and Ben Nevis.‡

* *R. A. S. E. Journal*, 1850, p. 10.

† Risler: "Geologie Agricole," Tome I., p. 45.

‡ Macmillan: "Holidays in High Lands," p. 49.

The pines and larches are magnificent on the decomposed mica-schists of the Highlands generally, but are poor, stunted sticks on the thin, cold clays of the granite.*

On the Kingsbridge estuary in Devon there is a flourishing vegetation on this rock, including orange and lemon growing in the open air, where sheltered from the south and south-west winds.† Further, I have noticed the rich green pasture and good "heath" land on the same formation near Knocklayd Hill, at Ballycastle, county Antrim; so that, while the contours and physical characters are rocky and rugged, the vegetation is generally of a superior class.

Serpentine.—Serpentine rock is really decomposed eruptive rock which may have been formed from gabbro, gneissic rocks, crystalline schists, or even from olivine rock. It is generally of a greenish colour, but sometimes we find it of a deep red, though, in fact, many varieties of stone known as green marble are only varieties of serpentine. It is, chemically, hydrous silicate of magnesia, and the colour in it is really due to the oxidation of iron. The whitish veins in the same are generally steatite or soapstone. The principal chemical ingredient of the rock, or the clays derived from the decomposition of the same, is magnesia. In the Lizard rock Prestwich states that there is 34·6 per cent. of magnesia present, while in the clays derived from the same there is 33 per cent. Wherever the serpentine rock occurs it is more or less rounded or even level in contour, and almost devoid of earth or vegetation. The soil on the serpentine plateau at the Lizard is exceptionally inferior,‡ and this is easily explained when we look at the chemical composition, as we know that an excess of magnesia is always hurtful to vegetation. We see the same thing in the case of the magnesian limestone, which cannot be used on land in the same way as the ordinary calcareous limestone can be used, and here in the serpentine areas we have also an excess of magnesia with a resultant want of vegetation. Sometimes, owing to the amount of iron and alumina present, associated with this large amount of magnesia, the soil (such as it is) is swamped with moisture. As a physical fact, we know that magnesian earth holds a greater proportion of water than any other, and, therefore, this magnesian soil tends to form

* Page: "Economic Geology," p. 36.

† De la Beche: *R. A. S. E. Journal*, 1842, p. 23.

‡ *R. A. S. E. Journal*, 1842, p. 29.

swamps and marshes. It is a curious fact that in Cornwall, and across the Channel in Brittany and the adjacent parts of France, and even in Spain, the Cornish Heath *(Erica vagans)* is found growing only on the outcrop of this formation in which magnesia abounds. In fact, the existence of this particular rock can be traced by the growth of this heath.

The poorness and moory nature of the soil in Cornwall of this rock contrasts greatly with the fertility of the soil on the diallage and the syenite alongside.

The serpentine soil in Cornwall is noted so specially and peculiarly that Karkeek classes it as one of his four Cornish soils.* There are sometimes veins of diallage and hornblende running throughout which yield a better soil, and higher rent per acre, and it is quite common to see soil on one field over these formations worth a good rent, and the soil over the adjacent serpentine worth practically nothing.

Diabase and Diallage.—This particular formation exists only in very limited areas. In the Meneage district of Cornwall diallage soils of a pure type occur on a small scale. This material contains apatite plentifully in the coast varieties. There is also a little calcite and biotite present, but the fertility depends on the proportion of hornblende in the original rock. The district above-mentioned is rugged and wild, very little regular farming is done, and the live-stock nearly all consisted of pigs in the olden days.

It is curious how the idea that the fertility of the soil depends on the nature of the minerals present in the original rock is borne out by the study of these soils. Risler says, "The series of rocks from amphibole, tremolite, actinolite and hornblende, or from pyroxene, augite or diallage, form, in general, soils more fertile than the corresponding rocks of the mica series." He says this is due to the comparatively slow decomposition of mica, but it is more likely to be due to the greater amount of plant food in the other minerals with, of course, more complicated structure and easier disintegration.*

While this formation is always hilly and rugged, the soil formed is a fairly good loam, as indicated above by Risler, and as exemplified at Saltash, near Plymouth, and on the farms of Barneil

* *R. A. S. E. Journal*, 1846, p. 404.
* "Geologie Agricole," Tome I., p. 44.

and Craighead, near Girvan, in the south-west of Scotland, but its area being limited it is of correspondingly little importance.

Hornblende Rock and Schist.—This particular formation occurs on a small scale at the Lizard, and yields an exceedingly fertile soil with low undulating contour. It contrasts much with the rough and sterile soil alongside, and, indeed, it is so fertile that the farmers of the district were in the habit of digging it up and carting it on to adjacent fields under the name of "marle soil" wherever they found a bed of this decomposed rock.

Another instance of the value of this formation is to be met with in the north of Ireland, as some of the igneous beds of the basaltic plateau of Antrim are formed of this material. At Knocklayd Hill, for instance, near Ballycastle, the green slopes are situated on this formation, and, in fact, some of the greenness of the country generally is due to its presence stimulating the growth of grass, owing to the presence of a plenitude of lime, magnesia, potash, and iron oxide.

Diorite.—This is a particular kind of igneous rock included in the old term "Greenstone." Greenstone in the old nomenclature was a general name given to some four or five rocks of an allied nature, such as diorite, diabase, gabbro, and basalt; but the term is now pretty well restricted to the first of those, and, as the name indicates, it is more or less of a greenish colour—in fact, in Scotland and the North of England it would be termed "Green Whinstone."

In the words of Risler, "Diorite is a rock of a granitoid structure which does not contain amphibole or common felspar as much as oligoclase or labradorite. Certain varieties of diorites, when found among others on the central plain of the northern part of France, are much charged with calcite, and give with acids a notable effervescence. It is probable that these are quartziferous diorites more or less altered."

Diorite generally occurs as intrusive dykes or sheets. Some of it is so rich in limestone that when it is decomposed it is used as a dressing for land, and in Brittany it is particularly useful in this way, and goes under the name of "marl."

The soil of diorite is particularly fertile, and on the Continent, when used as a dressing on other parts, helps the cultivation of buckwheat and ordinary wheat very much.

In this country dioritic soils are typically found in Cornwall. According to Sir Henry de la Beche, as quoted by Risler, near the Lizard, in the county of Cornwall, soils of great fertility are formed by the decomposition of syenites and diorites, and in another district the infertility of serpentine soils of the same neighbourhood is apparent. As the rocks of the Lizard are all exposed under the same conditions of climate, the contrast between the different degrees of fertility which is there found is very instructive and exemplary. The heights of the hills being about equal, the agricultural character of the soil depends upon the subjacent rock only. It would appear that the fertility of typical diorite soils is due to the presence of lime in the composition of the rock—or rather in the composition of the labradorite contained in it, and which is of course a silicate of alumina, lime, and soda—and also to the presence of hornblende. The composition of these minerals is such that weathering takes place rapidly, and consequently this particular variety of igneous rock becomes denuded more quickly than some others of this class, so that we get a fertile soil, or even a marl.

Professor Johnstone mentions that he had seen a tenant farmer removing twelve inches of this soil from the entire surface of a field, for the purpose of spreading a layer of an inch in depth over twelve times the area on another part of his farm, this soil being a trappean diorite.*

Even the one mineral hornblende, a component of diorite, when it occurs as a rock formation by itself in Cornwall, yields a surface of remarkable fertility, as noted above.

We thus see that either the diorite or its component minerals give rise to the formation of fertile soil material where the accumulation of débris has free play, as in Cornwall and the opposite coast of Brittany and Normandy—the soil of this rock being the same in both countries.

The character of the soil physically is pretty much the same all over in such widely separated districts as Penzance, Dunbar, and Wigtownshire. It consists of a dark brown loam with, of course, the native rock sticking up through it.

Basalt.—This term includes the varieties melaphyre and dolerite, the latter being the "toad-stone" of Derbyshire. The term

* De la Beche : *R. A. S. E. Journal*, 1842, p. 27.

"trap-rock" is a very general one, and includes several varieties of rock, but it is chiefly applicable to this, and the best example of the same is to be found in the north of Ireland in the basaltic plateau already mentioned. Typical examples are to be found at the Giant's Causeway, Fingal's Cave (Staffa), and Samson's Ribs (Edinburgh). It occurs in great sheets of rock, which have been looked upon as outflows of lava from great fissures in the earth's crust, in contradistinction to outbursts from volcanoes proper. The soil from the same yields a green sward of great fertility, owing to the presence of plenty of lime, magnesia, potash, and oxide of iron ; and, indeed, the name "Green" or "Emerald Isle" applied to Ireland is largely due to the pasturage which is fed by the soil of this formation.

Even where dykes occur the fertility is apparent, and an example is mentioned by Pusey * of a case near Closeburn, in Dumfriesshire, where on a moor lately reclaimed from heath, and then covered with coarse grass, a band of bright emerald green herbage marked the underground course of a trap dyke.

Much of the general good character of the soil over the Lowlands of Scotland is due to the fragments of this material which have been scattered about in bygone ages by glacial agency, which fragments have become decomposed to form part of the soil of the same; in fact, a trap-rock or basaltic rock always yields good soil, although it may form a desolate region where high above sea level and with an inferior climate.† This is well exemplified in Morven, in Argyllshire, where it yields many rich grasses, while in other more exposed parts it is only covered with heather.‡ In the words of Jamieson, quoted by Risler, regarding the Island of Skye,§ "The basaltic hills of Skye and the other islands of the West of Scotland are covered, even on their most abrupt sides, with admirable green pasture. Without doubt the climate here counts for something, as the inhabitants say that it rains there three days out of four. Irrigation is perpetual, but the contrast is none the less very great between the basalts covered with verdure, and the poor heathers which alone vegetate on the granites of the central massif of Scotland, and this contrast is only to be explained by the

* *R. A. S. E. Journal*, 1842, p. 28.

† "The trap-rocks of Scotland, so fertile in low situations, present a scene of desolation on the hills." *R. A. S. E. Journal*, 1850, p. 5.

‡ *Trans. H. A. S. S.*, 1878, p. 9.

§ Risler: "Geologie Agricole," Tome I., p. 136; also *R. A. S. E. Journal*, 1856, p. 467.

difference of chemical composition between the different variety of rocks."

"The capital of Scotland, Edinburgh, is situated on basaltic rocks. In all the countries which surround it—those of the Lothians, Haddington, Linlithgow, Stirling, Lanark, with those of Ayr at the west and the Cheviots in the south—the basaltic dykes form often the crest of the hills, and the débris of their decomposition, mixed with the less fertile earths of the coal-mine formations, &c., which are understood to be under them, serves them for natural amendment. Even, sometimes, the farmers dig up the altered basalt for transporting to their fields."

The historic farm of Fenton Barns, near Drem, is an example of this statement of Risler; two-thirds of the farm resting on felsitic trap-rock and one-third on the boulder clay. The former yields a red loam with rich grass where in pasture, while it was on the latter that George Hope carried out his world-famous improvements.*

It is a curious fact that the red broom-rape (*Orobanche rubra*)—a parasite on the roots of wild thyme—is only met with on trap or basaltic soils.†

The soil itself is a dark brown loam of great fineness of particles, and its character for growing *green* grass holds all the world over, though the scenery may be rugged from the protruding rock, as exemplified by such widely apart places as Antrim and the Mount of Montreal.

Of basaltic formations in other countries, one of the most interesting is the region in Palestine to the north-east of the Sea of Galilee, known in its various parts and in various ages as Bashan, the Hauran, the Lejah, Decapolis (from the ten important cities in it), and Trachonitis. The latter name, indeed, is simply from the Greek τραχωνίτις ("a rugged country") and derived from the same root as trachyte—a rock allied to basalt in origin and composition. This region is a basaltic plateau, culminating in the Hill of Bashan, or Jebel Kuleib, and cut through by many deep river valleys running mostly from east to west and draining into the Jordan. The disintegrated basalt yields a fertile soil, and in former ages, when the rainfall was plentiful, it was noted for both grain and cattle and sheep. The celebrated bulls of Bashan

---

* *R. A. S. E. Journal*, 1853, p. 317; also 1871, p. 166.

† Johnstone: "Agricultural Chemistry and Geology," 17th Ed., p. 158.

were grown on this formation,* also the rams of Bashan,† while it was equally well known for its wheat in Bible times,‡ and Thomson states that it is now, as it always was, the granary of Central Syria and Northern Arabia.§ Even the fertility of the plain of Esdraëlon—a rich loam—is believed to be partly due to the decomposition of the basalt,|| which breaks through the nummulitic limestone that forms the greater part of Palestine, and appears in isolated knobs like Tabor, Little Hermon, Gilboa, and Megiddo.

Felstone or Felsite.—This is a variety of igneous rock which has been erupted from below in sheets, veins, dykes, or bosses of very restricted surface area, and only having a comparatively small effect on the surface—scenic more than agricultural. It consists essentially of an intimate mixture of quartz (silica) and felspar, mostly of a reddish or brownish colour, and, curiously enough, weathering with a grey or whitish outside, forming many of the "moor-stones" found in some parts of the country. Being restricted in area, it can hardly be said to have much influence on the soil where it occurs, and one or two names of such places will best exemplify its nature: Dumbarton and Dunglas Castles, "doon the water" from Glasgow, sit on knobs of rock partly or wholly of this nature, while the Wrekin, in Shropshire, is a hill of this rock formed from altered perlitic pichstone.¶

Porphyry.—This name may be taken to represent a number of allied rocks which differ in some respects, but which may be agriculturally classed together. These are felspar-porphyry, porphyrite, hornblende-porphyry, granite-porphyry, quartz-porphyry, &c. Rough hills—rounded in form, with few actual crags or precipices, but high and rugged—characterize these rock masses covered with a "soil very ungrateful,"** where peat or glacial detritus do not cover the surface, and "afforested

---

* Hudleston: "On the Geology of Palestine," p. 42. *Proceedings: Geol. Assoc.*, Vol. VIII., No. 1. "When properly disintegrated this basalt tends, no doubt, to the formation of land such as that on which the bulls of Bashan grew fat in former days."

† Deut., chap. xxxii., verse 14.

‡ Smith: "Hist. Geogr. of Holy Land," p 83.

§ "The Land and the Book," p. 365.

|| Hudleston: "On the Geology of Palestine," *ante.*

¶ Prestwich: "Geology," Vol. I., p. 385.

** Risler: "Geologie Agricole." Tome I., p. 43.

PLATE III.

GRANITE BOSS, SILURIAN RIDGE, AND RIVER GRAVEL: CAIRNSMUIR-OF-FLEET AND RIVER CREE, N.B.

ARCHÆAN SCHISTS: GLEN DHRANE, LOCHINVER, N.B.

with pines" in many cases. A good many of the rugged parts of the country are formed of this material, and a list of some of the places where they occur will best illustrate the agricultural characters of the same: the Pentland Hills, Brown Carrick Hill (Ayrshire), the bleak moory hills above Lochwinnoch, Cader Idris, Camelford, and the "elvan" dykes of Cornwall, are the most typical; but many others could be mentioned, because rocks which might be classed as varieties of some of the above-mentioned occur in extensive areas all over the kingdom.

Penmaenmawr, on this formation in Wales, and Llandudno—an "island" of mountain limestone separated from the other by a narrow "strait"—illustrate in a remarkable degree the influence of different underlying strata on the natural vegetation. There are many plants found at Great Orme's Head which do not occur on Penmaenmawr, while the ferns *Hymenophyllum unilaterale* and *Allosorus crispus* grow on the Pen, but not on the limestone.*

Felspathic Group.—This name may be taken to represent some eight or ten different divisions on the geological scale of colours; they are all different, but of allied natures, and known to the geologists of the Survey under such names as felspathic conglomerate, felspathic trap, felspathic ash, felspathic calcareous ash, tuffs, and so on, while the volcanic agglomerate to which we assign the status of a separate important rock next in order is practically a variety also. The materials may be generally described as volcanic ejectamenta which have been deposited in beds over the then existing surface, and over which sedimentary or igneous beds were sometimes subsequently deposited. In common with most of all the other igneous rocks they occur only among the older strata, from the Archæan to the Permian, and are really varieties of material derived from volcanic vents which then existed in the neighbourhood where they are found.

The principal physical characteristic of these materials is their comparative looseness, and the ease with which they have become disintegrated. Interbedded with other and harder formations, their outcrop between the same has been partially protected from denudation, but where fully exposed they have been more or less smoothed down, and thus their surface areas are limited. Perhaps the best example of this group is the felspathic trap area of the

* Symonds: "Records of the Rocks," p. 87.

Cheviot range*, where the rock has weathered down into rounded hills, yielding a rich green sward.

Volcanic Agglomerate.—This term includes a large number of altered volcanic ejectamenta, such as dust, ashes, sand, lapilli, bombs, breccia, tuffs, and débris of all sorts. They occur in beds among basalt and such-like rocks, and also in "necks" of different ages. These beds simply represent the accumulation of this dry, volcanic material which has been ejected from vents in bygone ages, alternately with beds of basalt or other lava-like rocks. Sometimes it occurs in the form of necks which are really old volcanic vents filled up with this material. In the latter case, the remains of the volcanic cone have been eroded away, leaving these necks standing up as hills or knolls, sometimes very conspicuously. The material in general yields a soil of great fertility, as it is of very complicated composition. Where this occurs in beds it is not often that we find any very extensive surface outcrop, for the reason that it is only the edge of such beds where it crops out from below sheets of basalt, as in the North of Ireland, that we find the formation on the surface at all, so that there is very little soil of this type to be met with in the stratified form; but when we come to the case of these "necks," the matter is entirely different. To take one particular locality as an example: there is a district ten miles square in the Ayrshire coalfields where about twenty of these necks of Permian age stand up, and which give quite a peculiar style to the landscape. Seven of these necks form hills which are known to the inhabitants as "Greenhills," or the Celtic equivalent "Greenan," and are so indicated on the Survey Maps. These really are hills or knolls of greater or lesser size, and the material of which they are composed yielding such an exceptionally fertile soil is necessarily covered with a fine sward of close, green grass. In the old "folklore" days these were generally believed to be fairy hills, as the greenness of the grass contrasted in many cases with the poor soil surrounding, while the elevation naturally led the country folk to call them "Greenhills."

Many of these hills have no particular name at all, but the excessive richness and greenness of the sward is apparent all the same. Geikie says that they occur in considerable numbers over the whole Scottish Lowlands, and are all of carboniferous or

* Geikie (A.): "Geology of the British Islands," p. 103.

Permian age,* while the Geological Survey Memoir says that "each of those green hills is the stump, as it were, of an old Permian volcano."†

Grauwacke.—An indefinite term applied to some varieties of the older metamorphosed rocks in some parts of the country, chiefly of Silurian age. The typical form may be described as a cross between a slate and a sandstone. It yields, however, good soil in many places, and is of considerable extent. A strip of fertile soil on this runs from Torbay to Plymouth, and a portion of this rock near the Tamar, between Tavistock and Launceston, called "skillot," affords a soil of singular fertility, the grass lands yielding often from two to three tons of fine hay per acre, principally consisting of white clover. On this pasture it is affirmed that an ox will, from being quite poor, get moderately fat in ten weeks. As arable land, many parts are too forcing for the growth either of wheat or potatoes.‡

The soil is largely developed in Wales, but its fertility is much affected by the position and climate of a given district, yielding fair crops on the coast, but becoming barren on the mountains,|| a state of matters met with also in the Highlands and "Southern Highlands," where large tracts of country are underlaid by some variety of grauwacke.

ARCHÆAN.

Laurentian.—This is a name given to a series of formations which are most largely developed on the banks of the River St. Lawrence, in Nova Scotia, New Brunswick, Labrador, and the Lake district of Canada, and even as far south as the Missouri and New York State. It has sometimes gone by the name of "Old Gneiss," and is considered to be at the bottom of all the sedimentary rocks. Lithologically, it consists of gneissic rocks, more or less crystalline—metamorphosed—and containing such minerals as labradorite, augite, hornblende, and hypersthene rocks, while apatite occurs in workable quantities. There are also some rocks

* Geikie (J.): "Geology," p. 216.
† *Mem. Geol. Sur. Scot.*, Sheet 14, p. 23.
‡ De la Beche: *R. A. S. E. Journal*, 1842, p. 29.
|| *R. A. S. E. Journal*, 1850, p. 5.

described above occurring in the formation in greater or lesser quantities, such as hornblende rock, quartzite, dolomite, serpentine, and crystalline limestone.

Huronian.—This formation takes its name from Lake Huron, and consists of conglomerates formed from quartzites, felsites, and schists, but the materials are not so coarse as in the case of Laurentian.

The above two formations are represented within the British area principally by the "Fundamental Gneiss" of the Hebrides and the Western Coast of Ross and Sutherlandshire. (Plate III.) In these latter the rocks are represented by quartzose, gneisses, micaceous and chiastolite schists, chloritic schists, and crystalline limestones, in which mica schists predominate. These rocks generally form the most rugged, rocky, and bleak country, but where the eroded material does accumulate the soil is wonderfully fertile. These formations, together with the next, form the basis of part of the "Backwoods" of America, the Green Mountains of Vermont, and the "forest primeval" of Longfellow. As previously stated, an American authority* holds that the whole of the soils originally formed in this region have been swept off by glaciers and "dumped" into the Atlantic. If this is so it has made very little practical difference, because the soil which there exists now, if it does not belong to the subjacent rock, but has been brought from a distance further north, is exactly the same as if it had been produced *in situ*.

I have had an opportunity of holding a plough in both Vermont and Massachusetts, where these soils are typically shown, and when once the excessive quantities of boulders have been removed, the chocolate-coloured soil that remains is exceedingly fertile, and is of exactly the same nature as would be produced from the subjacent rock. In Sark, again, we meet with the most fertile soil of all the Channel Islands on the Gneiss rock, "and vegetation begins where mineralization ceases." †

In some parts, however, if the soil was ever formed at all it has been swept clean away, and I have seen regions for perhaps hundreds of miles along the Canadian Pacific Railway to Lake Superior that are absolutely devoid of any soil whatever. Trees always were able to grow in such a district, and it is amazing to

* Merrill: "Rock Weathering, &c.," p. 291.
† *R. A. S. E. Journal*, 1859, p. 66.

see how the pine trees of various kinds are able to send their roots into the crevices of bare rocks and obtain sufficient nutriment to grow into good timber.

In the North of Scotland it is certain that large timber did grow at one time, because in the peat mosses of that region we find enormous trunks of pines and firs, and also of oak trees, showing that when the climate was suitable the rock formation and the soil were quite good enough to grow forests of large timber. In our day, however, this locality is celebrated for its savage grandeur and for the stunted growth of everything thereon, for there are no trees or bushes on the barren heaths of Loch Torridon.* It was the scene of the famous "Sutherland Evictions" of a former generation, and of the Sutherland Reclamations of our generation. "The Duke of Sutherland, a descendant of him who at the beginning of our century had acquired a sad celebrity by taking the land of the poor tenants for replacing with sheep, which *pay better*, gives an example to all of improvement. He accomplished intensive culture on a grand scale, aided by all the resources which mechanics and modern chemistry were able to furnish him—steam power, portable railways, chemical manures. It is a noble revenge."†

Subsequent experience has shown, however, that in the climate of Lairg, and on a peaty soil resting on primitive rocks, it is not possible to carry out systematic arable farming so well as it could be done further south or under better conditions.

Pre-Cambrian.—In Pembrokeshire, Anglesea, and Carnarvonshire there are rocks of an Archæan age composed largely of quartz-schists, quartz-porphyries, quartz-felsites, and chloritic, micaceous, and talcose schists. These are considered to be rather later than the previously-mentioned rocks in deposition, and earlier than the typical Cambrian rocks. Possibly they may be of the Laurentian-Huronian age, but as we find them not only in the above counties, but also in Charnwood Forest and forming the axis of the Malverns, it is necessary to notice them. They are, of course, of a similar nature to those already described, and the contour of the country is of the same most rugged and inhospitable nature, the farming being confined to sheep and cattle, and these, of course, only of the mountain breeds. Charnwood Forest, in particular, has been described as "islets of slate rising up out of a sea of New Red

* Geikie (A.): "Scenery of Scotland," p. 112.
† Risler: "Geologie Agricole," Tome I., p. 116.

Sandstone."* According to the *R. A. S. E. Journal* the soil of Charnwood Forest is very inferior, although it has been much improved by modern cultivation.† Small areas of igneous rock which come to the surface show a much better soil, consisting of strong red loam, but this is very restricted in extent, while pine woods cover a part of the other rock surfaces.

In New Brunswick the sterility of the rock-débris on the Pre-Cambrian formation is noteworthy,‡ the soil being little more than "a mass of loose shingle, the result of ages of disintegration."

CAMBRIAN.

Regarding the rocks of the Cambrian series generally, if we go over the Atlantic we find that they constitute a great part of the eastern half of the whole continent of North America. They form, together with the previous group, the ground-work of the country known to our forefathers as "the Backwoods," the "Acadia" of Longfellow, the country of the "forest primeval," and it has been said, in reclaiming these rugged districts from the wilds, that some of the roughest work was done by the early pioneers. The author has known personally of men who have tramped into the thick of these woods with absolutely nothing in their possession but the head of an axe and a loaded rifle. To the axe a handle was roughly fitted, and they began to literally cut farms out for themselves from the thick wood, and now these farms to-day are some of the most desirable to be found on the American continent. The whole of the States of New England, and the whole of the eastern provinces of Canada as far west nearly as Winnipeg and as far south as New York, are composed of these ancient rocks of the Cambrian, Pre-Cambrian and Laurentian-Archæan series generally. In some places they are absolutely sterile, not altogether on account of the débris from them being of a sterile nature, but simply because there has been no soil collected on the top of the rock at all. Where the soil does collect it is generally of a fairly fertile description in some places, because there are sandstones, limestones, and volcanic rocks present, as well as slates and shales.

* Prestwich: "Geology," Vol. II., p. 24.

† *R. A. S. E. Journal*, 1866, p. 322.

‡ Chalmers: "Surface Geology of North-East New Brunswick," p. 31. *Geol. Sur. Canada.*

The timber that naturally grows on this rough ground is composed largely of pines, more particularly of the "hemlock" pine, which, imported to this country, goes under the general name of "American fir." This pine occupies thousands upon thousands of square miles of territory. The writer himself has travelled on the Canadian Pacific Railway through 1,100 miles of timber at one stretch. The timber, however, is not confined to pine only, for the sugar maple largely grows in New England, more particularly in the State of Vermont; while in the hollows down at the streams, where the land is more or less swampy from the remains of the old beaver dams, the ground is a tangled marsh of cedar woods, and nearly every hollow is more or less of a cedar swamp.

Coming back to our own country we may take up each formation of this series separately as far as we can.

Longmynd and Harlech Rocks.—The Cambrian formations as a whole take their name on account of the fact that they are most largely developed within the Welsh area—Cambria being the old name for a part of Wales. It comprises a great many different formations, but these are all more or less of a similar character. Notwithstanding this, however, we find that, taking each formation by itself, there is a difference each from the other as to the nature of the soils, contour, and general farming characteristics. The lowest beds of this system are those above-mentioned, and consist of conglomerates, grits, sandstones, and slaty rocks—red, purple, and grey in colour, and massive in deposition. They generally form an exceedingly rugged country, yielding poor soil, where it is the natural débris of the rock below. Of course, owing to the rugged nature of these rocks they are little cultivated and mostly in grass, and the farming confined to sheep and cattle. Indeed, the Longmynd itself is a hill, or rather a range of hills, in Shropshire, and which from time immemorial has carried a special breed of sheep of its own—the Longmynd or Kerryhill sheep. These, of course, in modern days have become more or less displaced by improved breeds, more particularly by the Shropshire breed which has come so much to the front within our generation; but still the fact remains that a particular geological formation, forming a definite range of hill land, has, in the course of ages, developed a special breed of sheep of its own. On the other hand, the Harlech formations have also become celebrated, not for sheep, but for men

—the Men of Harlech being as famous as those who grew on the schists of Assynt in Sutherlandshire.

In these formations there sometimes occur small thin beds of limestone, and where these come to the surface and affect the deposits we have patches of good land, more particularly of fine green pasture, and of course more or less in the hollows. These beds, generally, in a state of nature are largely covered with a growth of heath, furze, birch, larch, and rowan, these being in a sense the natural timber of this kind of rock.

Menevian Beds.—These beds consist of dark slates and flags forming a deposit totalling up to about 600 feet thick. They differ in composition from the Longmynd group, and are found mostly at St. David's, on the Pembroke Coast. They are, of course, of little account from a farming point of view, being like the preceding ones—exceptionally rocky and hilly. There are, nevertheless, different varieties of formations within this one group, and these may be distinguished into blue slate, giving an exceedingly unproductive soil, and grey shale, the soil of which is comparatively good. As they are limited to this particular corner of the country their agricultural characteristics are, however, of subordinate importance.

Lingula Flags.—This group of rocks takes its name from the fact that it contains one specific fossil in very large quantity, a variety of shell-fish known as *Linguella Davisii*, which in the older books on geology was called by the shorter name. These flagstones occur most largely in Pembroke and Merionethshire, and consist of large dark-coloured slaty rocks which split up into flagstones.

The agricultural characteristics are similar to those of the foregoing deposits—a rough country, much broken up with rock, and almost entirely devoted to sheep and cattle.

Tremadoc Slates.—The Tremadoc rocks consist of about 1,000 feet in thickness of dark, earthy slates and flags, which on account of their earthy nature disintegrate more rapidly than many of the others, and thus we find that where they occur near Portmadoc and St. David's the soil is a little more loose and earthy than with the others just described, though there is not much more fertility to speak of.

SILURIAN.

Llandeilo Flags, Limestones, and Conglomerates.—The term Silurian was applied by Murchison to certain of the rocks found in Southern Wales, in the region occupied by the old British tribe of the Silures, and the name has been adopted and now represents a vast accumulation of rocks, not only in Wales, but in many other parts of the country, particularly in the Highlands of Scotland and the Southern Highlands of the same country, together with many of the districts in the north and south-east of Ireland.

As a matter of fact, the finest scenery in Wales is on the Llandeilo formations, or on the Arenig formations which are sometimes looked on as the lowest beds of the former. It is sufficient to mention as an example of this, Snowdon and Cader Idris, and if we go to Cumberland, the green heights of Skiddaw —formed of "Skiddaw slates"—are reckoned of the same formation, so that we have these exemplifying the bold and rugged nature of the scenery.

In the case of some of these places last-mentioned there occur beds of volcanic ash—"felspathic porphyries"—and where these exist the soil is, of course, much improved, as otherwise the natural rock itself would yield material of second-rate quality.

The Skiddaw slate is more easily weathered than some of the adjoining formations—the Borrodale series for instance—and therefore the hills formed of this are smoother, and with more uniform slopes and more verdant pasturage.*

More than forty years ago a prize essay on the farming of Shropshire was published in the then current volume of the Royal Agricultural Society's *Journal*,† and in the same, special attention is called to the soils of the Llandeilo Flags. The writer describes them as fertile, arable soils and explains that they belong to the lighter class—*i.e.*, that they are easily worked and are good soils for turnip and barley growth: not very deep, as the flagstones come near to the surface and protrude in many cases, but still sufficiently deep to make it worth while to carry on cultivation.

According to Risler, "these calcareous schists whenever mixed with sandy beds furnish an excellent soil, among others, in the neighbourhood of Carmarthen."‡

* Woodward: "Geology of England and Wales," p. 37.
† *R. A. S. E Journal*, 1858, p. 1.
‡ "Geologie Agricole," Tome I., p. 175.

Being Silurian formations they are, of course, hard and indurated, and consequently the contour of the country is more or less rugged and elevated, but this does not detract much from the fertility of the arable area. Even in districts where the surface is too steep or rugged for cultivation the natural pasture is often remarkably good. An example of this may be given, occurring in the south of Scotland: the famous Passes of Enterkin and of Dalveen in the Lowthers are "nicks" in the hills, yet, though the slopes are steep, they are almost always grassy or heathy; and where the rock does roughen them it is for the most part only in detached little crags and hummocks. "The steep green declivities of the Pass of Dalveen, and of the minor valleys which enter into it, form a singular feature in the scenery of this region."*

A large proportion of the Southern Highlands of Scotland are on this rock, and the loams, full of angular stones, which cover the hillsides near Newton Stewart, Glenluce, Dunragit, and on the Girvan to Stranraer railway, are examples of the farming of this. (Plate III.) It is in this district generally of a dark reddish-brown colour, darker where the "shales" show up. Perhaps one of the best examples of this kind of country is to be found in the Machars of Wigtownshire, south of Newton Stewart, where the contour is low-lying and the soil fertile and moderately dry, though much broken up by rock.†

Bala and Caradoc Beds.—Speaking generally, these soils in Shropshire‡ are inferior and very variable in their physical composition unless lime is present. This lime is the weathered residue of what is known as the Caradoc Flags, composed of thin shelly limestone, which, wherever it occurs, readily weathers down and mixes with the adjacent formations and produces a soil of fair quality, or, at any rate, of quality better than where none of that limestone occurs.

Bala beds are slightly different geologically, and, of course, take their name from the town and lake of that designation, but agriculturally they may be classed along with the Caradoc, that is to say, Silurian soils, the contour of which is liable to be broken up by protruding slate of the same nature as a pretty large portion of Wales is formed.

---

* *Mem. Geol. Sur. Scot.*, Sheet 15, p. 6.
† *Trans. H. A. S. S.*, 1885, p. 93.
‡ *R. A. S. E. Journal*, 1858, p. 1.

These two, of course, are dissimilar in their nature, but are generally classed together geologically, as they practically form part of the same series. The Bala limestone is comparatively rich in phosphate of lime, which occurs in concretions, generally in former times dug out for manurial purposes; more recently it has been regularly mined for the phosphorite known as Welsh, Silurian, or Black Phosphorite. This occurs in a bed immediately above the limestone,* is from 10 to 15 inches thick, and was found by Voelcker to contain about 64 per cent. of phosphate of lime (tribasic). The utilization of other sourses of phosphatic material has, however, thrown this into the background. Wherever this limestone comes to the surface the conditions, of course, are better and the natural sward is better than on the adjacent ground.

The Caradoc sandstones are formed of yellow to dark-coloured shelly and calcareous sandstones, grits, and conglomerates.

Regarding these, Risler says†: "The bed of sterile sandstone carries nothing more often than heath. The inferior part, or the sands alternating with the beds of limestone, is more favourable for cultivation"; so that, to put the matter generally, limestone gives a good herbage while the Caradoc sandstones are covered with worthless heath. Taken as a whole, however, these beds occupying Mid-Wales form "desolate desert-like places." ‡

The Caradoc limestone in some parts yields one of the best limes for agricultural purposes, and as an example of this, the "well-known lime quarry of Craighead,"§ in Carrick, Ayrshire, may be mentioned.

Coniston Limestone.—In the neighbourhood of the lake of this name in Westmoreland there is a narrow belt of land which runs for several miles from Windermere to Shap Fell. This narrow belt yields herbage that is much sweeter than that on either side, and in fact has the appearance of a long strip of green carpet right across the hills, on account of its being so closely eaten down by sheep and cattle, while the herbage on either side is allowed to grow rough. This narrow belt owes its existence to the outcrop of a particular bed of Silurian limestone, called from the name of the lake, and its occurrence in the lake region is very

* Davies: "The Phosphorite Deposits of North Wales."

† "Geologie Agricole," Tome I., p. 175.

‡ Jerome-Harrison: "Geology of Counties of England and Wales," p. 338.

§ *Mem. Geol. Sur. Scot.*, Sheet 14, p. 9.

pronounced in its effects on the coutour of the country and on the vegetable growth on its surface. It forms, in fact, a long strip of what we should call "sound" land right across a moory district.

Woolhope Limestone.—A formation of an analogous nature occurs in a district of Hereford in much the same way as the last, and with much the same results. The Woolhope Limestone, however, is really argillaceous soil, but the beds of clay when weathered down to form soil are much modified by the nature of the intercalated beds of limestone which go under the above name. At Woolhope and Ledbury the stiff soils grow good examples of oak, ash, hornbeam, and willow; and this is the more noticeable because there are soils of a lighter nature occurring on the beds both below and above this particular formation.

Wenlock Limestones and Shales.—According to the abovementioned treatise on Shropshire farming,* the Wenlock shales make cold tenacious soils—excepting where the limestone beds crop out, when of course limey matter mixing with the clay tends to modify the same and improve it—but the soils are all of a curious liver or purplish-slate colour, from the fact, of course, that these Wenlock slates are simply indurated mud which has not become hard enough to form actual slate, but is getting on that way. The Wenlock limestone by itself makes useful tillage land, that of course means friable land, and the soils of the district may in this way vary from the stiff clay shales alone, through various mixtures of shale and limestone, until the light friable soil of the limestone is reached. It is by the occurrence of such formations in Welsh areas that the absolute ruggedness of Wales is redeemed, and large stripes and patches of land are of a fair arable value.

Ludlow Beds.—These beds produce soils of exceedingly various kinds, but are mostly of a clayey nature, though, curiously enough, this clay is more or less dry on account of the fact that the underlying rock is full of fractures, and these, as it were, supply the means of natural drainage, so that a few inches or few feet of clay on the surface is kept fairly dry by natural means. We thus have the somewhat anomalous condition of a dry clay. The soil, however, is only of second-rate character so far as fertility and

* *R. A. S. E. Journal*, 1858, p. 1.

agricultural value is concerned. In fact in Shropshire the shales of this formation form what are locally called "mud stones" and "slaty rocks," and when weathered down produce a soil that has always been characterized as "muddy" when wet. In connection with this group there is one little local formation called the Aymestry Limestone, from the town of that name. This limestone is of a hard nature and of a grey to bluish colour. Its outcrop is not sufficiently extensive to give it much of a special agricultural character by itself, but where it comes to the surface in connection with the Ludlow shales, and even sands, it modifies these very considerably, and, of course, in common with all forms of lime does good and converts what would otherwise be a very second-rate soil indeed, both physically and manurially, into one of a fairly good fertile character.

OLD RED SANDSTONE.

Tilestones.—These rocks form a sort of boundary between the Silurian formation and the Old Red Sandstones, and in the case of the Lesmahagow Tilestones they actually are generally included under the Old Red Sandstone group. They occur in thin laminated masses, and from their nature yield poor thin soils covered with heather and peat in both England and Scotland. In Shropshire these Tilestone beds are exceptionally poor, and, curiously enough, Risler calls attention to them and quotes a local saying in connection with them, "They eat all the dung and drink all the water"; in other words, they have got so little power of retention for either manure or moisture that their infertility is proverbial. This, of course, is natural when we consider that lithologically their material is mostly quartzite and the name of Tilestone is given to them on account of the fact that they split into thin flaggy pieces which are actually used for roofing purposes. In Lanarkshire, where this formation occurs, the elevation of the land is of course against it in the upper reaches of Clydesdale, but the material of which it is composed is so poor that the land is almost barren moorland – apart from its elevation—covered with heath or peat and yielding little useful herbage.*

**Trans. H. A. S. S.*, 1885, p. 8.

Old Red Sandstones and Conglomerates.—Old Red Conglomerate soils are typically exhibited in Shropshire in connection with the Tilestones. They are of themselves poor hungry soils of a gravelly nature, but when mixed with the clay and limestone material of adjoining formations they yield a soil of average quality varying in texture from gravel to loam and with the typical red tint from the amount of iron oxide present. The material being of a rather hard indurated nature gives rise to hilly ground, which cannot be called mountainous but which is nevertheless of considerable elevation. It occurs very largely in some parts of Scotland; at the hill called Corsincon in Upper Nithsdale, for instance, an out-lying spur of Old Red Conglomerate, the rock is there called "rotten rock," but this is simply from comparison with the other rocks of that neighbourhood. Of itself it is fairly hard, but when quarried out and used as road metal it breaks up and wears so much more rapidly than the blue or green whinstones (dolerite, diorite, trap, basalt, &c.) of the neighbourhood, that it has acquired this name. It is in southern districts, of course, that the typical soil of this formation shows itself on the surface. The Ryelands—so called because the poor sandy soil was only fit to grow rye in the olden time—is a typical example of these, and on which the Ryeland breed of sheep were developed; this being one of the progenitors of the now famous Shropshire Down breed.

Corn-stones.—This formation of the Old Red Sandstones is found typically developed in Hereford, Monmouth, and Shropshire in particular, and forms one of the richest and best soils that we meet with in the whole of the British Islands and also in many regions abroad. It is full of nodules of impure limestone which, when weathered and broken down, supply a large amount of calcareous matter, itself a manure and acting on the other portions of the soil to set free the fertility therein. As a matter of fact, it is the exceeding great value of this soil for arable land purposes that has given the name of "Corn-stones" to it, because the presence of the above-mentioned nodules causes the land to be practically of a gravelly or friable nature, while it is exceedingly useful for growing all sorts of corn. The alluvium derived from this formation is, of course, of extra great fertility, and an illustration of this is found in the Valley of the Dor—sometimes called the "Golden Valley" solely on account of its great agricultural richness—and in that of

the Lugg.* Indeed many valleys or districts which go under the name of "Golden Vales" or "Golden Valleys" in their respective localities—such as in particular the "Golden Vale" of Tipperary in the south-west of Ireland—are situated on this formation.

The oak is the tree specially characteristic of the same, but unfortunately it grows too quickly to produce sound timber. The natural growth of oak is indeed so excessive on this formation that it has sometimes been called the "Weed of Hereford," in the same way as the beech has been called the "Weed of the Cotswolds." This and the next one (Old Red Marl) are the great formations for orchards, as on no other does the apple flourish so well, either in Hereford, Devon, or Ontario; while one leading geologist points out that the orchards of the Carse of Gowrie (an Estuarine Clay) owe their existence to being underlaid by these formations,† the Carse itself being derived partly from the débris of the Old Red formations to the north-west.

The hop lands of Hereford and Worcester are also on these concretionary limestones and corn-stones.‡

So celebrated was this soil for growing wool in the olden time that old Fuller describes that of the Golden Vale in Hereford as so long and lustrous in its fibre that the flock-masters there ought not to envy that of the Tarentine or the Apulian, and described it as "known to the honour thereof as Le'mster ore," while its wheat was as good as that of Heston in Middlesex for "pureness." §

The famous "Laigh of Moray" is situated partly on this and partly on the Old Red Marl, and thus varies from stiff to light land, but both help to make it a splendid arable country. It is, indeed, reckoned one of the finest agricultural districts in the kingdom,‖ though so far north, and wheat ripens further north on this soil than on any other.

Old Red Sandstone and Marl.—This soil is one of the richest in Great Britain, if not the very richest and best, taken all round. It is, of course, reddish in colour as becomes all the formations of the Old Red system, though sometimes when the "marl" is dug up

* Jerome-Harrison: "Geology of Counties of England and Wales," p. 118.

† Ramsay: "Physical Geology and Geography of Great Britain," 3rd Ed., p. 272.

‡ Johnstone: "Agricultural Chemistry," 18th Ed., p. 120.

§ *R. A. S. E. Journal*, 1868, p. 275.

‖ *Trans. H. A. S. S.*, 1884, p. 7.

from a depth where it has not been affected by the atmosphere it may be slightly green in colour. It produces what might be called a strong loamy soil, and examples of it may be given by way of illustration. The famous red soil of Dunbar, the red soil of Wales, and the highly-rented market garden soil of Cornwall (Lelant) are examples of the best soils of this formation. Risler describes it as a healthy fertile loam, in some places of a class light enough to be described as turnip and barley soil. In common with others of this description it is, of necessity, good in quality for all sorts of crops and practically in all sorts of climates, as we find examples of it ranging from Caithness in the north to Cornwall in the south, and westwards into Tipperary and Limerick in Ireland.

The farms on the red soil of Dunbar are rented at up to £5 per acre, and an example of the influence of the soil on the crop may be given in the case of the potatoes grown thereon, and compared with others grown elsewhere: "Dunbar reds" are usually quoted in London at more than double the price per ton given for "Blacklands" from the Fen soil. The speciality of the former is that after cooking they may be re-heated several times without loss of appearance or flavour.

In America, the Upper Devonian soils as a whole are remarkably fertile, but as the divisions as given by American geologists—in the State of New York at least—cannot be exactly collated to the British formations, a general statement only of the farming characteristics of these can be made. The Genessee Valley with its proverbial wheat lands; the oak openings of Ohio; and the heavy pine lands of Michigan, are all largely confined to soils of Devonian origin.* On the Canadian side, the "Garden of Canada,"† celebrated for its apple orchards, like the same formation in Hereford is on the beds of the Old Red Sandstone. The Devonian soils of the Rhine valley are another example of the fertility of the best strata of this group. The Old Red Marl, indeed, in Britain is better adapted for fruit trees than any other.‡

It is noteworthy that the term "marl" as applied to this formation is inappropriate; the intercalated beds are really soft and friable shales with no lime in their composition at all. § (Plate IV.)

* Stockbridge: "Rocks and Soils," p. 16.
† Gresswell: "Geography of Canada," p. 43.
‡ Ramsay: "Physical Geology and Geography of Great Britain," 3rd Ed., p. 272.
§ Page: "Geology," p. 197.

PLATE IV.

OLD RED SANDSTONE SOIL: DUNBAR, N.B.

SECTION OF OLD RED SANDSTONE SOIL: DUNBAR, N.B

It is necessary to point out that geologists do not consider the Old Red Sandstone and the Devonian to be equivalents; but as lithologically and agriculturally they are very similar, they are here discussed as one series of rocks.

CARBONIFEROUS.

Lower Carboniferous Shales.—These formations occur under or at a lower part of the Coal Measures, and they consist of shales—*i.e.*, clay that has been deposited in beds and partially hardened—and when exposed at the surface and weathered produce poor, unproductive, stiff soils. A typical example of this occurs in a strip from west to east of Durham, from Cockfield to Woodland, and consists of poor, shallow, barren, clayey soil. The clay predominates, and a special feature is that this clay is deficient in lime. Owing to the fact that these beds are not indurated they weather down pretty easily, and their existence is the outstanding reason why the Coal Measures generally yield poor clayey soils. The sandstones and limestones which constitute the other members of the Coal Measure System resist weathering to a very large extent, and therefore they supply very little material to form the surface of their respective districts; but the shale, on account of its comparatively soft nature and its extensive occurrence in beds which differ slightly from one another, furnishes a greater part of the material for the making of the soils of the Coal Measure areas. The clay in itself is generally of a bluish or drab colour, which weathers to a yellow or brownish red. In every case it is an exceedingly ungrateful soil to work with, and one that requires thorough draining and large doses of lime and farm-yard manure to make it even second-class arable land.

A large proportion of the Boulder Clay over the Lowlands of Scotland—in the coal districts—is formed from this stuff, but the draining, manuring, and general good farming of that region has done much to make it capable of growing good crops.

This poor yellow clay soil is a very general feature of this group, for we find it in a locality in the West of England, between Launceston, Hartland, and Okehampton, "the most dreary and barren in the district, a poor yellow clay being the common product of the decomposed shales and sandstones there found."*

* De la Beche: *R. A. S. E. Journal*, 1842, p. 26.

Mountain Limestone.—The Mountain Limestone takes its name from the fact that it occurs in huge masses in various parts of the British Islands, more particularly in that range of hills known as the "Backbone of England," running from the Weaver Hills in Staffordshire right to the "Borders." It is known as Mountain Limestone because it really forms in many cases not hills but actual mountains. It consists of more or less impure carbonate of lime, of a greyish or bluish colour, and is *par excellence* the best kind of limestone for burning for farm purposes that we have. Although it quite forms mountains in some parts, with much of the rock actually bare, yet its universal characteristic is, that though covered with a very thin, loose, rubbly soil, composed of vegetable mould and small fragments of the rock, the pasture on the same is of an exceptionally sweet and nutritive character. Where an earthy soil is formed it consists of a brown loam—the residue of the dissolved limestone—as exemplified at Cheddar, Harrogate, Wensleydale, Haddington, &c.

In the Cumberland district farmers have told me that they have turned out sheep on to these bare limestone rocks, where scarcely any grass was to be seen at all, and yet after a few months they have come off as fat as pigs, without any artificial feeding whatever. It is on this formation that the sheep's fescue grass (*Festuca ovina)* grows to the greatest perfection, and this may have something to do with the special value of this particular formation for sheep pasturing purposes. So suitable is it for sheep that on the ridge of high country between Yorkshire and Cumberland there are several distinct breeds recognised by all writers on live stock, as also in the prize lists of our different agricultural societies, and which are all more or less peculiar to, and developed upon, a Mountain Limestone substratum. There is, first of all, the *Limestone* breed itself, then another breed known as the *Lonks*, also the *Silverdales*, and lastly, the *Penistones*—the latter being one of great importance in its own district, although that district is only comprised within an area of some 25 miles square.

Risler gives the Mountain Limestone the credit of being the formation on which the Shorthorn breed of cattle was developed* ; and there is some reason for this when one looks at a geological

* "Geologie Agricole," Tome I., p. 185. "La célèbre race des *shorthorn* a été formée sur les herbages qui couvrent le *mountain limestone* dans le comté de Durham."

map and sees how many of the farms and estates where the breed was first made famous, and where it is yet kept in the highest state of development in Cumberland, Northumberland, Durham, and Westmoreland, are situated on this formation.

Some special examples of Mountain Limestone farms may be given by way of illustration :—For instance, in the neighbourhood of Butterton, in Staffordshire, the richest grass in that county is to be found.* Possibly the name of the village itself may have been taken from the butter-producing qualities of the pasture in the olden times.

In Derbyshire the soil is a thin ferruginous loam, good for sheep pasturing†; but Sheldon points out a peculiarity in the hay-making on this formation in that district, as compared with that on adjoining loamy land overlying the Yoredale Rocks and Millstone Grit. On the limestone the hay needs a day longer in the sun than on the other soils, and may have to be put up temporarily into cocks or "quiles," while it can be stacked in a softer condition on the loams of the latter without fear of undue "sweating."‡ The pastures in the neighbourhood of the Dove—where old Izaac Walton plied his art—are proverbial for their grazing qualities on this rock.§

Again, in Monmouthshire, where this rock comes to the surface the sweetest pasture is found. In the Gower of Glamorgan, and also in Pembroke, sweet close pasture is the characteristic of this limestone. It is only in the extreme North of England, in Durham, where we find a limestone region bleak and poor, but in this particular instance it is more or less due to the fact that the limestone rock is overlaid with a deep drift accumulation—this "drift" being really the actual formation. Massive beds of this limestone form the Mendip hills: the well-known Cheddar cliffs are formed by a transverse rent through these rocks, and it is just possible that some of the quality of the original Cheddar cheese, which took its name from this district, may have been due to the mixed pasturage of the limestone rock, along with that of the adjoining low-lying Keuper Marl. (Plate V.)

One notable point in connection with this is the quality and keeping power of the milk produced on this as compared with that

---

* *R. A. S. E. Journal*, 1869, p. 311.

† Woodward: "Geology of England and Wales," p. 86.

‡ *Agricultural Gazette*, August 10th, 1891.

§ *R. A. S. E. Journal*, 1853, p. 17.

from some other formations. To take a case in point: In the London milk trade it is well known that the produce of the Derbyshire limestone is considerably richer in composition, and will keep from souring at least a day longer than the milk from the Essex and other clays; the lime seems to have both a productive and an antiseptic effect.

This particular limestone formation passes under the great Triassic plain of Central England to appear in the picturesque hills of Derbyshire, the bluffs of the Matlocks, the scarps of Dovedale, and the high ridges of Buxton, in Yorkshire, and the basis of the famous pasturage of Craven. The limestone hills, which rise to heights of 2,000 to 2,500 feet, in the fine range of the Pennine Chain are intersected by many beautiful dales so characteristic of that district, such as Wensleydale, Swaledale, Dovedale, &c. The prevailing clear cold-grey colour of the limestone throughout this range—frequently the bare surface—and the innumerable caves, render these rocks easily recognizable, and contribute greatly to the scenic effect in the districts they form. The plateaux of limestone in Lancashire (Morecambe Bay), Westmoreland, and Yorkshire (Settle), are often bare of vegetation for miles.*

It is rather curious, however, to find that this formation forms the basis of the great "Central Plain" of Ireland, whereas in England and Scotland also it occurs always in the hilly or mountain form. In Ireland it has been levelled off to form a huge plain, which is overlain more or less now by peat formations, of which the famous Bog of Allen is one of the largest and most notable examples. In the west, however, as in County Clare, the country is mountainous, the hills composed of bare limestone rock, with scarcely any soil at all. The richest herbage grows in the clefts and furrows of the rocks, and the land is worth a good rent, "for there is no sweeter mutton than that fed in Burren."† It is notable that white clover springs up abundantly on this limestone of Central Ireland—being an acid-hating plant—and that even on the overlying bogs and surface accumulations it springs up spontaneously as soon as a heavy dressing of lime is given.‡

* Ramsay: "Physical Geology and Geography of Great Britain," 3rd Ed., p. 561.

† Westropp: "Physical Geology of North Clare," p. 77. *Jour. Roy. Geol. Soc. Ireland*, 1872.

‡ Johnston: "Agricultural Chemistry and Geology," 17th Ed., p. 161.

In other countries the grazing qualities of the Mountain Limestone soils are just as conspicuous. The renowned "blue grass region" of Kentucky is an important instance in support of this fact.* The "blue grass" is our *Poa pratensis*—"smooth-stalked meadow grass"—and one generally reckoned of only secondary quality, but which comes out "top" when its roots are on the limestone rock.

This limestone, in common with many of the other forms—especially the chalk—is remarkably dry and free of surface water, even in a wet climate. In the west of Ireland, for instance, there is little or no water on the surface. This is due to the fact that the rock is full of fissures, while the dissolving power of water containing carbon dioxide acting through unnumbered ages has formed caves and underground channels in which the water runs. The Derbyshire caves are examples of the former, while underground rivers are one of the peculiar features of this formation in every region where it occurs.

Yoredale Rocks.—The upper strata associated with the Mountain Limestone is so distinguishable from the same that it is classed under the above designation from the district of the same name in Yorkshire.

The general characteristics of the Yoredale formation from an agricultural point of view are inferior. The "Black Shale" forms a strong soil—*i.e.*, a clay soil—of a dirty drab to blackish colour, and at Grindon, in Staffordshire, this particular soil—undrained—rots the sheep badly.

The natural growth on the surface generally is a good indication of the outcrop of this rock, as we find a preponderance of furze, heath, whortleberry, and sorrel, and the Mountain Limestone next to it is generally pretty well defined by the vegetation on the surface. The Mountain Limestone gives a short, sweet sward, as already stated, while shales and sandstones of the Yoredale series give a growth of the inferior plants just mentioned. A particularly good example of the change between the two is shown at Oakamoor, in Staffordshire, just below the Weaver Hills. Scots pine is the prevailing tree on the Yoredale formation, while as soon as you cross the line on to the other the same tree ceases to thrive and we get good pasture. Both the rock and the shale yield a bare, moory

* Stockbridge: "Rocks and Soils," p. 23.

country, examples of which occur at Bell Busk (Skipton), near Kendal, for the "rock"; and at Harrogate and Kirkby Stephen for the "shale."

Millstone Grit.—The Millstone Grit, as its name indicates, is a coarse, gritty sandstone of different colours, and sometimes almost passing into a conglomerate. In the olden days it was a variety of rock much used for the manufacture of millstones, from which it took its name, as its coarse, gritty nature suited it for this class of work.

This and the Mountain Limestone nearly always occur together surrounding our coal-fields; in fact, the normal formation of a coal-field is a hollow, saucer-shaped depression, surrounded by a rim of hills or mountains composed of Limestone and Millstone Grit in adjacent beds. The Grit, however, is of such inferior nature for agricultural purposes that it forms an extraordinary contrast to the adjacent Limestone. The rock itself is so absolutely poor in plant food, and so absolutely devoid of all soluble material, that it is a known fact that the purest water in England from natural sources is derived from the Millstone Grit hills.

Indeed, the streams which drain the Millstone Grit areas are so excessively pure that the ordinary aquatic plants refuse to live in them, and the water is therefore of great clearness and limpidity. Wherever, indeed, this rock occurs, the surface, if not absolutely sterile, is certainly very inferior. In Monmouthshire, for instance, it is only suitable for sheep walks. In some places the soil is so inferior that it is with difficulty that a fair quality of milk can be got from the cows pasturing on it—a liberal allowance of artificial food doing little to help the same.

In a garden at Oakamoor, in Staffordshire, known to the author, the roses always degenerate on this soil—the red turning pale and tending to "hark back" to the original *Rosa canina*. Near the source of the Derwent, in Derbyshire, on this formation there are patches of soil, sometimes of many acres in extent—called, from its colour, "foxearth"—of a poor ferruginous nature; nothing grows on it excepting beech. The soil of these patches is deficient in all those ingredients most essential to plant growth.*

The soil and grass is very inferior in Staffordshire, and in Pembrokeshire it is considered not only unproductive, but even poisonous. Indeed, not a single good word can be said in favour

* *R. A. S. E. Journal*, 1853, p. 42.

of the Millstone Grit as a formation on which good farming can be carried out. Of course, little or no cultivation can be attempted on ground that is mostly hilly or rugged, but the natural herbage on the same is always more or less inferior and the districts nearly always moory. In fact this rock itself in some parts of the country is known as "moor rock."

The hills are generally terraced and steeply scarped in contrast to the more rounded and "broken" hills of the Limestone formation. A large part is covered with peat moss, as the surface of the rock is retentive of water and generally elevated, while, when this is drained and cultivated it yields a scanty soil—hungry, and sandy or gravelly. Some of the districts are called "forests," without now having a single tree on them. A most undesirable formation for farming purposes in every way.

It is curious that this formation has often little or no "till" or drift on it, even in highly glaciated districts, and the explanation offered by some geologists is that the rougher nature of the surface helped to grind down the mineral débris embedded in the ice to finer material, and the ice at the same time into water, so that no deposit was made, but everything carried off, thus leaving the bare rock to form moors.

Rugged hills, poor sandy soil, moors, a growth of beech, pines, and birch, with no undergrowth, all characterize this rock. The most suitable timber for plantations is the Scots pine—the safest to grow on this class of soil.*

Coal Measures.—The Coal Measures proper may be looked upon as an example of Nature witholding her hand in one direction and giving out her gifts liberally in another. The exceeding great value of the mineral riches of the Coal Measures is more or less of a set-off to the exceeding misery and poverty of the soils on the same. Wherever these formations occupy the surface we have, of course, a very thick population devoted to coal mining, iron mining, and all the hundred and one industries which are dependent thereon, but the surface formations, the soils, and farm characteristics ·generally are the reverse of desirable. Even in Devon and Cornwall, where there are no workable seams of coal, the shales and other beds of this particular group yield an exceedingly bad soil, poor, sterile, and scantily populated†; indeed,

* *R. A. S. E. Journal*, 1853, p. 65.

† Jerome-Harrison: "Geology of Counties of England and Wales," p. 66.

they form a yellow clay from the decomposed shales, as may be seen in the district between Launceston and Okehampton as mentioned above. In Glamorganshire they form poor moorland. In Pembroke, the shale beds form an actually poisonous soil on account of the amount of pyrites—*i.e.*, sulphide of iron—present in them. In Worcestershire, at Dudley Pensax and Bewdley the surface of the soil is poor and of little value; and so on, up and down the whole of the country, wherever the Coal Measures occupy the surface, we have an inferior farming district. In fact, these generally go by the name of the "Black Countries," and this name is not given wholly on account of the fact that there are so many coal-pits, furnaces, chimneys, and other smoke-making and blackening works, but because the soil of the farms, and the farms as a whole, are of a dark, dirty "*blae*" colour, and because the farming crops are injured and fouled by the excessive quantities of smoke which hang about manufacturing districts.

Even in the west of Ireland, where there is no actual coal, the country is brown and black compared with the green and grey of the Mountain Limestone adjoining; the former worthless moorland, and the latter good grazing land though rocky.*

These black countries, as it were, break through the great regions of fertile land formed in the Midlands by the "Red Sandstones and Marls," and it is sufficient to mention the Dudley coal-field, Ashby-de-la-Zouch coal-field, Warwick coal-field, North Stafford coal-field, and so on, forming, as it were, black islands in the middle of a sea of red sandstone and red marl.

The surface of the Coal Measures, though uneven, is very seldom hilly, the ground having an undulating contour. The coal itself does not, of course, break down to form a soil anywhere, but only the associated shales, and therefore the soils are typically stiff clays —in the northern glaciated regions a stiff boulder clay. Lime has great effect, and, when well cultivated, good crops are produced.

It is more than a mere accidental state of matters that on the Coal Measures of Eastern Canada clay soils predominate and lime is also required. Chalmers says that for the improvement of the soils overlying the carboniferous area lime appears to be the great *desideratum*.†

---

* Westropp: "Physical Geology of North Clare," p. 75. *Jour. Roy. Geol. Soc. Ireland*, 1872.

† "Surface Geology of North-East New Brunswick," p. 29. *Geol. Surv. Canada.*

In Durham the surface is a soft loam resting on a yellow ochreous clay, designated *water-shaken**—really a boulder clay derived from these shales. In the Ayrshire and Lanarkshire coal-fields the same state of matters predominates—a dirty blue clay, weathering to yellow or brown, forming the boulder clay there. The nearness of some other beds—notably trap and other volcanic rocks—has improved its quality, while the style of farming followed has developed the resources of the same to the utmost.

Perhaps nowhere is the comparative value of the sandstones of this formation shown than at a spot near Keynsham, on the Avon, between Bristol and Bath. An alluvial meadow there, formed by the washings of the Lower Lias and the Keuper Marl, was formerly let at £7 10s. per acre per annum, as it would fatten a bullock-and-a-half per acre per annum without cake; while the adjoining ridge of sandstone rocks of the Coal Measures is simply a piece of waste, broken land, covered with copsewood and scrubby trees, and of nominal value only.

It is not within the province of this volume to enter into social questions, but I cannot pass from the subject without calling attention to the fact that, apart from the soil and the physical characteristics of the district, farming carried on in the middle of coal-beds and furnaces, and so on, is at a very great disadvantage on account of the social antagonism of a mining and manufacturing population to one of rural pursuits. The coal miners, iron smelters, and others of this class, are not given to treating their farming neighbours with much consideration, and footpaths, and even public highways through the land, become almost unbearable nuisances; indeed, any benefit that accrues to the farming population from the nearness and greatness of the market for farm produce is more than counterbalanced by the trouble and misery from the population among which the farming has got to be carried on; while in the matter of wages the competition forces up the rate of pay above what farming can now afford in these days of keen foreign competition.

The following quotation from a writer of 50 years ago shows that this trouble is no new feature. Dr. Bell, describing the agriculture of Durham, says:—"I may be allowed to point out the great obstacle to the improvement of agriculture or the cultivation of the surface of this county, which arises from the immense

* Morton: "On the Nature and Property of Soils," p. 77.

wealth which has been, and still is, derived from the minerals beneath. No other county is so interwoven with a network of public and private railways. In no other is there so large a quantity of land occupied by collieries, manufactories, quarries, waste heaps, &c.; and in none, perhaps, is there a more extensive trade carried on in the working, manufacturing, and sale of coal, limestone, ironstone, and lead—all inducing a sacrifice of the interests of the surface for the sake of what lies below it. There is an enormous amount of trespass involved in all this trade. The pitmen especially are notorious for making roads for themselves in every direction, just as their necessity requires. Fences are destroyed, and crops are too often trodden down. This is disheartening to the tenant . . . . fresh heap-room is required, or it may be new waggon-ways have to be formed; and the farmer begins to grow careless of agricultural improvement when he finds that all his improvements bid fair to be destroyed by fresh requirements of the colliery owners, or by the trespass of a reckless population around him." *

"Surface damage" or "double damage" does not make up for the destruction of the peace or amenities of the farm, while colliery managers seldom take the trouble to keep their men in hand as well as they might do, and are disposed to treat with contempt the troubles and complaints of the rural population. Unless, therefore, there are some great counterbalancing privileges in individual localities, as sometimes happens, the Coal Measures are undesirable formations to farm upon.

PERMIAN.

Red Sandstone and Breccia.—This is Red Sandstone which lithologically cannot be distinguished from the corresponding beds of the Old Red. The typical developments of soils of this nature occur in such places as at Mauchline, in Ayrshire; the lower part of Nithsdale, in Dumfriesshire; the vale of Eden, in Cumberland; and the neighbourhood of Coventry and Exeter in the south. It may be classed as a first-class mellow red loam, a good barley and turnip soil, on which is met with some of the finest farming in the British Islands. The districts where it exists offer a complete contrast to the neighbouring carboniferous deposits; the stone itself is easily weathered, and the soil is naturally dry, on account of the fissures in the rock below, and as

* *R. A. S. E. Journal*, 1856, p. 95.

it has the usual characteristics where a large proportion of the oxide of iron is present, the normal fertility is first class. The natural herbage is good, and it is exceedingly suitable for sheep-feeding or folding.

The river courses are generally characterized by deep ravines or glens, as on the Ayr, the Eden, and the Exe (Silverton). Apples grow well on the formation, as do all hard timbers, while the plantations are characterized by a strong growth of underwood. Everything on it, of course, partakes of the universal red colour—even the alluvium off it; while, for instance, the sludge below high water at Exmouth is of a red to purplish colour. The "drift" in glàciated districts is also a red sandy loam.

The Esk River, on the Borders, runs partly through this and Triassic rocks, and Lady Nairne noticed with an observant eye that in flood-time the water runs red with silt, as she tells in a verse of the famous song, "The Hundred Pipers":—

> "The Esk was swollen sae *red*, sae deep,
> But shouther to shouther the brave lads keep;
> Twa thousand swam ower to fell English ground,
> An' danced themselves dry to the pibroch's sound."

Magnesian Limestone.—The Magnesian Limestone forms rather a narrow outcrop extending in a long strip from Nottingham to Tynemouth, in the West Riding. It is only about seven to eight miles wide, and though further south the outcrop is a few miles wider, still it appears on the map as simply a narrow ribbon running north and south.

The Magnesian Limestone, as its name indicates, is a rock which contains a large proportion of carbonate of magnesia, and is a strong, solid, crystalline rock, of a grey or buff colour, yielding blocks of every size and very suitable for ornamental architecture. The aspect of the formation is rather plain and level, there being no hills of any magnitude.

In average samples the carbonate of magnesia exists to the extent of about 44 per cent., and the soils formed from its denudation contain a notable proportion of this ingredient. In a sample from Derbyshire of a typical soil of this formation there was present 4·23 per cent. of this compound.

It is usually considered that Magnesian Limestone is not suitable for dressing land, because carbonate of magnesia is reckoned to have exceptional burning power on the vegetation and to render the soil, if not actually poisonous, at any rate inimical to plant life; but this does not seem to do any harm to the vegetation

over the actual rock, where the soil is thin and light, though it is not so fertile as other limestones.

In Derbyshire, the soil is of a chocolate brown colour, open, friable, useful, but not a rich soil. William Smith, the "father" of English geological science, gave the name of Redland Limestone to this formation on account of the prevailing tint of the soils of the same.*

It does not do well in grass in the West Riding, and the same may be said of Derbyshire, where the pasture tends to run to "shar" grass.† The prevailing natural grasses are Meadow Fescue *(Festuca pratensis)*, Meadow Poa *(Poa pratensis)*, Timothy *(Phleum pratense)*, Soft Brome *(Bromus mollis)*, Wood Brome *(Brachypodium sylvaticum)*, and the Pinnate Brome *(Brachypodium pinnatum)*, and these tend to grow in separate clusters. The last-mentioned grass is peculiar to this formation in Yorkshire, while the Cocksfoot *(Dactylis glomerata)* does not grow on it at all.‡ It is, indeed, a fairly typical turnip and barley soil, and within recent years the growth of swedes has become so successful as to be quite noteworthy, while lucerne and sainfoin have been almost dropped out of cultivation altogether. It, of course, requires to be well managed, and the folding of Leicester sheep is one of the principal departments of farm work.

The agricultural character of the soils over the whole of this formation maintains great regularity, the variations in quality being strictly due to the geological influences of the different beds.§

It is a curious fact that guano does not suit this soil in Yorkshire. Possibly the presence of such a large proportion of carbonate of magnesia may react chemically on the same, and in Derbyshire the application of liquid manure has been a failure. This would appear to be due to the pores which are open under the subsoil, the rock being very absorbent of water; and thus this special formation is not suited to the use of rich manures. Little cheese is made on this soil, sheep being the principal stock.

At Pontefract, in Yorkshire, on the "Pontefract Sandstone," it is noticeable that the cultivation of liquorice root, for the manufacture of "Pomfrey Cakes," is special and peculiar to the Magnesian Limestone soil,|| while furze grows naturally to a magnificent size.

---

* Fream: "Soils," p. 118.

† *R. A. S. E. Journal*, 1853, p. 20.

‡ Thorp: "Agriculture of Magnesian Limestone in West Riding," p. 118.

§ Ibid., p. 97. || Ibid., p. 98.

CHAPTER VII.

FORMATIONS AND FARMING.—II.

SECONDARY OR MESOZOIC.

TRIASSIC.

The Lower New Red Sandstones and Conglomerates (Bunter).—This formation is the basis of some of the poorest light sandy soils that we have in the whole of the British Islands. The mention of the name of some of the areas on this formation is sufficient to indicate its nature. One of the most important of these is Cannock Chase, in Staffordshire, about 13,000 acres in extent; also the adjacent Teddesley Warren and Whittington Heath; also Sherwood Forest and part of Beaudesert. These districts are literally barren, sandy hills, and being in a region where the glacial deposits are almost wanting, show up their own special nature to the fullest extent. A large amount of heath and bracken cover them, of course, and the Cannock Chase whortleberry may be said to be almost a specific plant, while birch and Scots pine grow readily when either naturally or artificially planted; but ordinary farm plants—even grass—can scarcely be said to grow at all. The hills are curiously rounded in appearance, while the soil—if it may be called soil—is almost barren sand.

In the northern part of Staffordshire the same formation produces the same sort of soil, a poor reddish sand, on which the beech is indigenous, while in Nottinghamshire it forms a light sterile soil*; but one particular fact that has been learned by the writer is that in gardens on this formation the ordinary red roses tend to lose their colour, and become pale and unhealthy in appearance, just as was described in a case on the Millstone Grit. New rose bushes brought from good nurseries "run out," as it were, in this way in the course of two or three years. It would seem that the soil has not strength enough or quality of itself to cause the healthy growth of these.

* Jerome-Harrison: "Geology of Counties of England and Wales," p. 209.

The Conglomerate—as represented by Cannock Chase—is, if anything, worse than the Sandstones, but both are pretty bad: waste land, fit only for sheep runs or rabbit warrens.

Curiously enough, both Cannock Chase and Whittington Heath, and even Teddesley Warren, had special breeds of sheep of their own in olden times, and, in fact, the modern Shropshire breed is said to have some of the old Cannock Chase blood in its pedigree. These varieties are, of course, long extinct as special breeds, and being on practically the same formation and in adjacent areas there could not have been much difference between them; but, nevertheless, the fact remains that they were classed as separate and distinct breeds by old writers*, the Whittingtons being larger than the Cannock Chase.

Waterstones.—Waterstones are in themselves variegated sandstones, the prevailing colour of which is red. The soil from these is usually reckoned first-class sheep land of good light soil, but requires good farming, as in many cases it does not yield a good natural pasturage. The prevailing tree growing on it is the birch; while the beech, larch, Scots pine, and plane also flourish. In some cases the beds are exceedingly poor in character. The famous gardens at Alton Towers, in Staffordshire, are situated on this formation, where it forms a poor red sandy soil. It is here that it was said of the owner that "he made the desert to blossom as the rose"—in other words, by a tremendous outlay of money, he converted the barren sandy ravines into lovely gardens clothed with all sorts of trees, evergreens, shrubs, and flowers. While good farming may be made to pay on the same, its natural fertility is rather small. Indeed, when it is stated that part of Cannock Chase is situated on this formation, those who know that district will have a very good idea of the nature of the soil and farming suitable. Yew-tree Farm was reclaimed from Cannock Chase in 1820, and much land in that neighbourhood has been reclaimed in the same way, and responds to good farming, although the natural pasturage cannot be praised. A very large proportion of peroxide of iron is present, though not so much as in the regular Red Sandstone formations. Other typical examples of soils of this formation are met with near Kidderminster, Stockton-on-Tees, and Lymm (in Cheshire), while on well-farmed soil of this formation at Altrincham

* Martin: "The Sheep," p. 27.

the red carrot of that name first came to the front on land much devoted to market gardening. At Kidderminster it is actually a "blowing sand"—a marine deposit from the "straits" which once separated Wales from England.*

Upper New Red Marl (Keuper).—The Keuper Marl is one of the most notable formations that we meet with. It is lithologically a red clay, and necessarily the soil on the top is also a stiff red soil. Of course this description does not hold right through everywhere, because we may find strains of sandstone among the marl, thus lightening up the same and making the soil more friable; but the general description of this soil is that of a stiff red marly soil.

It forms one of the best soils that we have wherever this formation occurs, and the names of some districts where it is found is sufficient indication to those who are acquainted with their farming of the nature of the soil. The alluvium of the Trent and the Dove is composed largely of the washings of this soil, forming the "Eden of Derbyshire."† Redditch district, in Worcestershire, a most valuable place for apples, pears, and hops, is on this soil. The richest soil of Staffordshire, full of little ponds, which mark the sites of marl-pits—where the marl was dug up in olden days to spread on the surface—is on this; and the same may be said of Cheshire and Somerset. In this latter county the Giant Orange Mangold grows to perfection on this soil. The "Red Ground" of Devon (Vale of Taunton) where the best orchards of apples are found for cider making,‡ is also on this, and the best apples grown in Nova Scotia are on the sandy marl of this formation in the Annapolis Valley—"the fruitful valley" of Longfellow's "Acadia." The Vale of Evesham is partly Keuper Marl and partly Lias Clay, the joint of division being very plain across the fields, owing to the different colours of the two formations. Being a stiffish soil, fully two-thirds of it is in grass, and grass of a superior quality, but it is not too stiff for two-horse ploughing, and for yielding good crops of all kinds. The fields are always divided by good strong hedges, and all kinds of hard-wood timbers grow to perfection, particularly the elm, while the soft-wooded poplar also thrives. It

* *R. A. S. E. Journal*, 1867, p. 440.
† Ibid., 1853, p. 58.
‡ De la Beche: *R. A. S. E. Journal*, 1842, p. 25.

forms excellent corn land in Derbyshire, being rich in phosphates,* while teazles are grown on it in the south.†

The most notable point about this particular soil is the fact that it is the foundation of some of the best cheese-making districts of England. The Vale of Berkeley, famous for cheese, is situated on this; but more important still is the fact that the village of Cheddar, at the foot of the Cheddar cliffs, is situated on a strip of this particular soil; and the name which has been given to the kind of cheese which is most widely manufactured throughout the civilized world is taken from a district which is typically a Keuper Marl. It is not an accidental circumstance that the best cheese-making districts in Somersetshire, Stafford, and Cheshire are all situated on the Keuper Marl, as first pointed out by Professor Sheldon, including the famous dairy farm of Croxden Abbey (late Mr. Carrington's) and others.

It is a curious fact that it is the *red* marl that is most valuable; blue marl is poor, while the red is fat and unctuous.

Rhætic or Penarth Beds.—These particular beds form part of what are called the "transition series" between the Mesozoic and the Kainozoic divisions of the rocks, and are very limited in their development in the British Islands, but in some districts on the Continent they are exceedingly important. They take their name, indeed, from the Rhætian Alps, where they are most largely developed. The material is partly clay in its nature in this country, and the soil derived from the same is of a dark grey or black colour, the original material being, indeed, dark grey or black shale, sometimes showing the junction with the beds below across the ploughed fields.‡ Examples of the soils on this formation are to be found in Somersetshire—at Tilbury Hill, Wells—and again more particularly in a narrow strip across the Cleveland district of Yorkshire, where, for instance at Eston Grange, the soil is a dark clay, mostly in grass. As it is only of limited occurrence, there are no special farming features connected with the same.

LIAS.

Lower Lias Clay.—The general character of this group is that of an unimprovable, stiff brown clay soil, more or less level or

* Jerome-Harrison: "Geology of Counties of England and Wales," p. 60.
† Woodward: "Geology of England and Wales," p. 130.
‡ Ibid., p. 146.

undulating. The beds themselves consist of dark clays, shales, and some thin beds of argillaceous limestone, which, when burnt, yields an hydraulic cement. The soil, consequently, wherever this formation occurs, is more or less of a clayey nature, which varies slightly according to the under-associated beds. At Shepton Mallet the soil is a dirty, dark clay loam; at Glastonbury, a brownish clay; at Marton, in Yorkshire, adjacent to the Red Marl, it is a reddish-brown clay, and so on; but always of a tenacious, clayey nature. This forms the soil at Shepton Mallet which scours sheep and cattle. It is considered by some that this is due to the excess of sulphate of magnesia (Epsom salts) present in the soil, and thence in abundance in the herbage.* As it is almost always in grass in the dairy districts, it is given up to the pasturing of dairy cows, and though the character of the soil is second-rate in some places, yet it must be noted that there are one or two Lower Lias Clay districts which are noted for their farming. The famous Vale of Evesham is situated on this formation, also the Vale of Gloucester, the Vale of Berkeley—the above three known locally as "The Vale"—and the Vale of Glamorgan; while the Marshwood district, in Dorset, though a "terribly rough" country, yields the famous Dorset butter.† This variation is, of course, due to the particular mixture with adjacent beds which occur in any given district in the formation of the soil on the surface.

In the "Vale" above mentioned the line of demarkation between the brown clay of the Lias and the red clay of the Keuper Marl is in many places distinctly seen across the fields; a clod picked up on the Lias shows a laminated structure, while the other shows no structure—the red land caking most after rain.‡

It is a soil that is suitable for the growth of fruit, and the conversion of some of the stiff land into fruit gardens has been one of the most notable things done in this line, plum fruit especially having been exceedingly successful; but over soils of this formation generally orchards and bush fruit have done very well—as in the Vale of Evesham.

The oak tree is one of the most important of its products, the famous oaks of Bagot Park, in Staffordshire, being examples of what it can produce in this line, while thorn fences are exceedingly

* Lloyd: "Board of Agriculture Report on Cheddar Cheese-making," 1899, p. 55.

† *R. A. S. E. Journal*, 1855, p. 420.

‡ Ibid., 1850, p. 147.

strong in growth on it. Of smaller plants, it has been noticed that the Field Foxtail grass (*Alopecurus agrestis*) grows on this formation very plentifully in the Vale of Gloucester, as also do wild oats. Coltsfoot is a troublesome weed on it in some districts, while teazles are grown on it. Of more valuable plants, Dogstail and Cocksfoot grasses suit it exceedingly, while, indeed, the pasture land generally is very good. At Eston, in Cleveland, the "Yorkshire Fog" (*Holcus lanatus*) grows to such perfection on it that some fields full of this are known as "sugar and cream" pastures, from the quality of the dairy produce yielded by them, though this grass is reckoned of only third-rate quality in some parts of the country.

The land is generally undulating, and not found in the dead level of some other of our clay formations—more especially the Oxford Clay—but is too heavy for much cultivation, and is, therefore, most largely left in grass. In many districts which were in cultivation long ago during the era of dear corn, old high-backed ridges are common, now laid down in grass, and still retaining their high crowns and deep furrows between.

Dairying is the principal industry—the "double Gloucester cheese" having originated on this formation, and still most largely made there—but in some districts other departments are attended to. In the Vale of Glamorgan, for instance, Hereford cattle are the favourite stock, while the great hunting and stock-rearing pastures of East Leicestershire are on the same. In Northamptonshire, the district from Banbury to Market Harborough is mostly in pasture, and sparsely inhabited.*

Marlstone.—The Marlstone itself is principally a grey limestone rock intercalated with clays and sandstones, these latter generally of a brown colour on account of the plenitude of iron ore; indeed, some of the Cleveland iron-fields are situated on some beds of this formation. The soil varies somewhat in different districts. In Leicester it forms free-working brown loam—good corn and turnip soil on some of the hilltops—and from its colour is known locally as "red land"; while the name of Rutlandshire is believed to be a corruption of "redland," from the prevailing colour of the soil there on this formation—as at Oakham and elsewhere—the adjacent clay formations being in grass.† In Somersetshire the limestone forms a brashy soil, very dry and liable to injury from droughts.

* Jerome-Harrison: "Geology of Counties of England and Wales," p. 194.
† Ibid., p. 218.

At Bridport, in Dorsetshire, a rich genial soil, "which can grow anything." The flat-topped Marlstone hills in Gloucestershire, and on Edge Hill and all round Banbury, are marked by a strip of peculiarly fertile soil.* It is, indeed, generally a good arable free-working soil, particularly suitable for the growth of lucerne. In Somersetshire some of the associated sandstones are, of course, rather poor, and where these beds come to the top, as in Yorkshire, they generally form hills covered with the Scots pine. In Lincolnshire it yields a rich brownish loam, which grows excellent wheat.†

The *Sandy series* of the Marlstone, as exemplified on the farm of Captain Swan, Upsall Hall, near Ormesby, in Cleveland, is a dark loamy turnip soil—the formation bluffy, with mixed woods and furze on the bluffs of the flat-topped hills, and grassy.

The *Ironstone series* at the same place is composed of a yellowish sandy soil, the ferruginous sand showing on the bluffs, with Scots pine as the prevailing tree. The soil is there a poor yellow sand, derived from horizontal beds forming flat-topped ridges, with "combs" or gullies running into the same.

The Upper Lias Clay.—The predominating lithological character of this formation is grey shale, clay, and marl. The formation takes the form of a low valley at the bottom of the Lower Oolite, or slopes from the escarpment of the same; the surface of the latter being undulating, but not hilly. In some cases, as on Glastonbury Tor, it forms hills where another formation has protected the same. The soil formed from it is, of course, more or less of a cold, tenacious, clayey nature, and is necessarily largely in grass. In some places it weathers to a dark brown or buff to yellow clay. In cases where the Oolite is overlying the same there is generally a good supply of springs, as from its retentive nature it retains the water that percolates through the superincumbent beds of Oolite, throwing the same out along the outcrop. The land is, of course, mostly in pasture, and, indeed, forms some of the best pasture in England, though it is sometimes wet and marshy as at Bredon, in Worcester. In Leicestershire (at Market Harborough), in Yorkshire, in the Vale of Gloucester, and so on, we have examples of the fine pasture lands to be found thereon, while Stilton, Gloucester, and Leicester varieties of cheese may be said to be indigenous to this formation. Crossing over to France.

* Ramsay: "Physical Geology and Geography of Great Britain," p. 273.
† Jerome-Harrison: "Geology of Counties of England and Wales," p. 157.

we find that the Charolais breed of cattle are nearly wholly indigenous to the same, and for this reason have been called the "Race of the Lias."*

The clay itself, when freshly dug from a depth, is dark blue in colour, almost blackish, but it generally weathers to a brown or yellowish soil; a loamy dark brown, for instance, at Kettering.

In some places, it is, of course, under cultivation, as at Castlethorpe, near Fenny Stratford; but it is customary to see three to four horses in a line in the plough; and though it grows good crops when properly tilled—especially beans—it is much better in grass, unless there are special reasons for the contrary. Poplars, elms, and apples do well on this soil.

Midford Sands.—This name includes several distinct formations, only one of which, indeed, is specially known as the Midford Sands. The lithological character is that of a yellow quartzose sand forming a rich sandy loam, light coloured, and dusty when dry. In Yorkshire, where it is slightly ferruginous, it is known as "Dogger Soil." In Somerset it is an exceedingly fertile soil of the lighter class, such as is met with at Newton Farm and Stoford, near Yeovil, the fine light soil at West Coker, and the yellowish sand at Bridport. It sometimes forms conspicuous grassy knolls, of which Glastonbury Tor and Brent Knoll are good examples.

It forms good arable land of the lighter class, while the grazing is also good—mostly devoted to dairying in the West of England. There are some fine cider-making orchards on the same, as at Hazelbury Manor and West Coker, near Crewkerne.

OOLITE.

Inferior Oolite.—The Inferior Oolites are mostly found to be represented by ferruginous Oolitic brashy soil, which, like others where several different beds come together, varies somewhat in different districts, being calcareous, ferruginous, or micaceous in different parts; but for the most part it consists of a brown, light, brashy loam, and, indeed, forms rather a weak, friable soil. In

* Risler: "Geologie Agricole," Tome I., p. 262. "Le Lias est la terre par excellence des riches herbages. . . . C'est là qu'on a formé cette belle race de bêtes à cornes que l'on appelle la *race Charolais*, et qui se répand peu à peu dans tout le centre de la France. . . Je pourrais presque dire que la race Charolais *est la race du Lias.*"

some parts of Oxfordshire, for instance, it is little better than blowing sand—as at Hook Norton, Tadmaston, Sibford, and Epwell—while in another part of the same county the district formed by this formation was called by Arthur Young the "Glory of Oxford."* At Essendine, near Peterborough, it forms a light-brown brashy soil, growing larch in abundance, and being more or less hilly and undulating in all districts. It is good healthy land for sheep, and, indeed, Cotswold sheep may be looked on as the special breed suitable to the same, but where it has been cultivated, as in Oxfordshire, it tends to form red land. Superphosphate has been found to give the best results of any manure applied.

It tends to form bluffs, with combes between, with good mixed timbers, among which elm and beech predominate; a state of matters met with at Bath, Sherborne, and the Cleveland Hills.

The "Northampton Sands" of this group form a rich but rather light soil in Northamptonshire, and a light reddish soil, good for spring crops, in Lincolnshire and Rutlandshire.† The same holds true of the "Lincoln Limestone."‡ On the former oats do not thrive owing to its light, dry nature.

Fuller's Earth.—This formation consists of a brown and blue clay, or, at any rate, it weathers brown when exposed to the air. It has been used for ages, of course, for fulling purposes, and though its development in England is comparatively small, it yet has a distinctive influence on a strip of country where it comes to the surface. Like the Upper Lias Clay it is exceedingly retentive of water, and, consequently, the rainfall which percolates through the overlying Oolitic beds is thrown out in springs along its outcrop. The soil forms a stiff, dark-brown loam, chiefly under grass in Dorset, sometimes mixed with Stonesfield Flags, as in the Sapperton Valley, in Gloucester, though sometimes it appears as a wet clay, more especially where the springs are thrown out. It forms an exceedingly good pasture ground, naturally rich in clover—as at Manor Farm, Hazelbury, near Crewkerne, and at Vallis Farm, near Frome—and well suited for the growth of crimson clover.

---

* *R. A. S. E. Journal*, 1854, p. 198.

† Jerome-Harrison: "Geology of Counties of England and Wales," pp. 166, 195, and 218.

‡ Jerome-Harrison: "Geology of Counties of England and Wales," p. 220; also Woodward: "Geology of England and Wales," pp. 172 and 182.

On this, not only some of the finest wheat, but also some of the finest apples are grown. Indeed, the orchards on the same in Somersetshire and the West of England generally are specially famous for the cider made from the apples grown in them.

It is noteworthy that in renneting the milk and scalding the curd in cheese-making a temperature higher by from 1 deg. to 4 deg. Fahr. is required on this soil than on the adjoining Midford Sands, thus illustrating the general fact that clay formations generally require a higher temperature in the process than do the lighter class of soils.

The *Fuller's Earth Rock* included in the group differs from the "Earth" itself, being a nodular limestone coming between the upper and lower beds of the other. It yields a brashy soil, the fields separated by dykes built of the blocks, while the country tends to be hilly, and with rough waste land, as at Milborne, in the West of England, and Essendine, near Peterborough. It is mostly in grass, for though the soil itself is a light-brown loam, the "Rock" is too plentiful to allow of much cultivation.

Stonesfield Flags.—Stonesfield Flags are shelly Oolitic limestones, which split into thin slabs, and being largely used in their district for roofing purposes, were by the older geologists called "slates." The soil formed from this formation occurs mostly in Gloucester and Oxford, in an outcrop along the sides of the valleys, and which can be traced for miles, in some cases, from the richness of the natural pasture on the same. These flags are particularly rich in phosphates, which are considered to have been accumulated from the remains of fossil insects as well as shell fish, and the result is that the soil is well supplied with phosphatic material, and thus the clover and other leguminous herbs are stimulated in their growth.

The soil varies from a friable loam to a typical "brash" on account of the limestone splitting or breaking up into small square or rectangular pieces. Indeed, these pieces of limestone are so thick that most of the fields might be said to be perfectly covered with a mass of stones. The country where this formation exists is, generally speaking, a table-land; the limestone beds having resisted denudation as a whole, but being cut across by valleys with streams, leaving elevated flat sections of country between.

The Great Oolite.—This formation—sometimes known as Bath Stone on account of its development near that city—is the principal formation of the whole Oolitic series, giving, indeed, the name to the same. It consists of a shelly freestone, or impure limestone, and is, indeed, one of our most valuable building stones in the South of England, as it lends itself so easily to cutting and carving with the mallet and chisel. The soil derived from it is full of calcareous fragments, without any sand, and, indeed, in some districts is called a "Stone Brash"—as at Stony Stratford, where it forms a blackish soil,* though it is of loose, loamy texture, and dry in its nature—while it again forms an excellent "black" soil in Rutlandshire.† It does not need draining, as the natural drainage is good enough; while, though it is formed from material that is calcareous, it is sometimes actually benefited by an application of lime. On the Cotswolds, bone-dust has been found the best manure to use, better even than dung itself. Of course, lime is not always required, but Risler points out that on the Continent, where this soil is largely developed, it is often of a dead or sleepy nature, and has been much improved by a top-dressing of lime. Owing to its dryness turnips often fail, although it is really a turnip soil, and is chiefly in arable crops—wheat, barley, oats, turnips, and clover—while on the stony varieties sainfoin grows particularly well. It is essentially a sheep-folding soil, and the natural productiveness of the same has been much improved thereby.

Where this series predominates the country is often rough and hilly, with much broken land among the protruding rocks and combes, as at Box Tunnel and in the neighbourhood of Bath. While the soil is light in texture, it is generally in grass on such broken land, with pinewood plantations, though the beech is the predominating tree.

The Estuarine Clay beds of this series in Lincolnshire constitute a cold, unkindly land, as exemplified in the "heath" at Little Bytham, and the same in Northamptonshire. It forms a cold, unkindly soil at Luffenham Heath and Empingham Wood, in Rutlandshire.‡ A comparatively barren soil.§

---

* Jerome-Harrison: "Geology of Counties of England and Wales," p. 196.
† Ibid., p. 220.
‡ Ibid., pp. 167, 196, and 220.
§ Woodward: "Geology of England and Wales," p. 187.

Bradford Clay.—This formation takes its name from Bradford, in Wiltshire. It is a pale blue clay, lying over the white limestone of the Great Oolite. It weathers down to a calcareous clay soil, very unmanageable, as exemplified at Frome, and southwards from that town. The soil is pale brown to brownish red in colour, exceedingly adhesive in its nature, and sticking to the plough in such a way as to need the lubrication of the mould-board with water, while four horses in a line is a common requirement. As to fertility, it is poor, and would be much better left in grass altogether, though, of course, drainage and cultivation improve it greatly.

Forest Marble.—Whichwood Forest is largely underlain by the Great Oolite formation, but there is on the top of it another formation which actually takes its name from this "forest" on account of being most largely developed there, and is therefore known as "Forest Marble." It is not a marble in the proper sense of the term, but as some of the beds form a compact, grey limestone, which, when cut and polished, is rather ornamental, the term "marble" has been given to the same. It is generally an argillaceous and rubbly grey limestone, which weathers down into a heavy, brown, brashy soil, well adapted for cultivating the growth of oak, elm, and ash, and of orchards. On the Cotswold hills this formation is particularly infested by the Field Foxtail grass (*Alopecurus agrestis*), while on the whole the soil can only be classed as a second or third rate heavy loam, carrying thin pasture in the natural state. The features of the country are bluffy, with mixed woods, among which beech predominates. In Dorset it forms a poor, wet soil, all in grass.

Corn Brash.—The Corn Brash itself is practically a variety of limestone with partings of clay, and it yields a soil which is full of angular fragments of the same, being called a "brash" for this reason. As it was good for corn growing in the old days when wheat was the most valuable crop of the farm, this specific name was given to it also, and it, of course, still maintains its character for good "corn." The soil is generally from three inches to a foot deep, a strong, red-brown clay-loam, and the districts where the formation predominates are generally composed of flat table-lands, with bluffy "edges" and combes. Stone fences are common, and the fields are generally large, as, for instance, in Oxfordshire, more particularly at Chipping Norton. From its friable nature, it is

mostly arable land, very suitable for folding sheep, though sometimes, where intercalated beds of clay predominate, the land is stiffish, three-horse soil. The angular fragments of limestone give great fertility, while on the stiffish parts beans grow exceedingly well. The soil is reddish in colour as at Sharnbrook, near Bradford (Wiltshire); and where cheese-making is practised it is found that a lower scald is necessary for the curd than is required on stiffish soil in common with other limestone soils, as practised at Seymour's Court, in Somersetshire. In Oxfordshire, superphosphate has been found to be the best general manure, although it is the richest in phosphate of lime of any of the other oolitic strata,* and there is generally plenty of lime present in the soils. The elm is the principal tree, more particularly in places where the soil is deep and loose. In Lincoln, potatoes grown on this soil become black after boiling.

As it is only some 20 to 40 feet in thickness it forms only a narrow strip of land—running up through the Midlands and Lincolnshire, as far north as Yorkshire. It forms a red soil of no great fertility in Lincoln, a poor reddish soil in Northampton, a red brashy soil good for wheat in Oxford, an earthy limestone good for corn in Somerset, and good corn land in Wiltshire.†

Kelloway Rock.—This formation is named from Kelloway's Bridge, near Chippenham, where it is typically developed; it is a grey, sandy limestone; in Yorkshire a calcareous sandstone, which, though about 80 feet in perpendicular thickness, is of comparatively local and narrow surface development. It forms a light soil, as exemplified on part of the farm of the Royal Agricultural College at Cirencester, which is partly situated on the outcrop of this rock. It is, indeed, a light soil exceedingly suitable for folding sheep and for alternate husbandry.

Oxford Clay.—This is a dark-blue tenacious clay of a calcareous and even septarial nature, and, on account of this, sometimes called "Clunch" Clay. When weathered into soil it yields a dark-brown brashy material, though in the Bedford levels it is of rather a bluish-brown colour. It forms a typical clay soil of varying retentiveness and adhesiveness, the contour of the country undulating but rather flat, with a great want of springs. It underlies the Fens, often at the distance of a few feet only under the surface of

* **Woodward**: "Geology of England and Wales," p. 195.

† **Jerome-Harrison**: "Geology of Counties of England and Wales," pp. 74, 167, 197, 214, 237, and 285.

the peat, and can be dug up and spread over the surface. It is exceedingly expensive to work, and is for the most part in grass or woodland, as at the Forest of Braydon, in Wiltshire. The district on this formation in Buckinghamshire has been called "an unhappy country." Orchards do well on the same, while the oak and the elm flourish, and at Berkley, in Somersetshire, teazles are cultivated. The soils on this formation form a long stretch of land, reaching throughout two-thirds of the length of England from north to south, and forming, in conjunction with Kimmeridge Clay, "the Clays" of the midlands, there being no very clear line of division between these two from Acklam Wold (Yorkshire) to Oxford, a distance of 240 miles.*

In Bedford and Northampton it is a close, heavy, compact clay, difficult to plough, except between the wet and the dry. It is a dirty soil in wet weather, a dusty one when dry in spring-time. It is a deceptive soil when dry, as it looks like a good loam, but is thin and poor. Clover and wheat are thrown out by frost, and then the dry winds blow them clean out of the soil. Corn comes up luxuriantly, and then "goes off" in May if the season is damp. It is, perhaps, one of the most expensive of all the clays to cultivate, though where mixed with the peat that overlies it in some places it becomes one of the most productive soils in the kingdom.

The remains of a bygone era of cultivation is found in the old high ridges or stetches—now in grass—winding in an S-shaped manner up and down the fields.

Being mostly in grass, it is generally given over to cattle husbandry, and some of the good dairy districts—as, for instance, at Bicester—are situated on the same. Cheese-makers find that the curd requires a higher scald than is necessary with limestone soils, but it suits dairy farming very well. In Buckinghamshire, for instance, the whole of it is given up to this branch of farming. No springs are found upon it, as it is too close and impervious, and for this reason the surface is wet. The richest and most productive pastures are found upon it, however—most luxuriant in Wiltshire, Gloucester, and Oxford, though it is not so good in some other districts.† The famous Wiltshire cheese is one of the products of the best samples of its pasture, while in the poor districts ant-hills abound, as on other poor clays.

* Jerome-Harrison: "Geology of Counties of England and Wales," p. 22.

† Morton: "Nature and Property of Soils," p. 54.

Calcareous Grit.—This is a coarse, shelly, oolitic sandstone, which weathers down to an easily-tilled, light root land. Some of the fields at Headington Hill, near Oxford, are typical soils of the same, and also Bradley Farm, at Cumnor. Where the soil is wet the carnation grasses (*Carices*) develop most largely, and seem, indeed, to be among the typical plants favouring this and the associated formations. The stone itself is worked for building purposes, but weathers easily on account of the amount of calcareous matter present in the same.

Its districts are often rough and hilly, and wooded—Scots pine predominating—from the plenitude of the rock, while the fences are often stone dykes of this material.

Coral Rag.—This is a hard, gritty limestone which weathers down into a red-brown, sandy, arable soil, full of calcareous fragments—forming, indeed, stone-brash soil in Wiltshire. The coarse, sandy soil at Headington Hill belongs to this formation, and it is of a hungry nature, yielding bad, benty pasture, full of *Carex*. A similar soil is met with in Berkshire, and as far north as Filey and Scarborough on the Yorkshire coast.

The general features of this and the associated Upper and Lower Calcareous Grits are undulating, hilly, and wooded with larch and pines, with a poor, sandy soil, which, however, responds well to sheep-folding and root-growing.

Kimmeridge Clay.—The Kimmeridge Clay is a dark-blue clay, very much like the Oxford Clay but better in quality than the same. It weathers down to a stiff, brown soil, more or less level and undulating; a stiff clay in Lincolnshire, good meadow land in Oxfordshire, and stiff clay soil at Kimmeridge, in Dorsetshire, from where it takes its name. Blackmoor, on this formation —and the Oxford Clay—in Dorset has an exceeding rich soil, forming a "happy vale" as the term goes. Another good district is the Vale of Aylesbury, where the clay is blue or grey, and slaty in nature, with selenite in the same. It is all in grass, and in this district is exceedingly good owing to the débris from the overlying Portland Stone being mixed with the same. Some of the land on this formation will fatten a bullock to the acre without cake, letting at £3 per acre near Gillingham; while for sheep the Hampshires are found to be the most suitable breed.

Oaks grow so well on it that William Smith gave it, as well as some other clay formations, the name of the "Oak Tree Clay," owing to the marked predominence of this tree on the outcrop in Norfolk.

Portland Stone and Sands.—The Portland Stone may be described as a calcareous freestone, while the associated sands are more or less glauconiferous. It is somewhat like the Coral Rag in nature, and forms arable land of a dry, sandy or loamy character—"a poor stone-brash soil." A typical soil of this formation is to be met with at Stone, near Aylesbury, where the British Dairy Farmers' Association first started a dairy school. It takes its name from the Isle of Portland, where it is typically developed, and where, indeed, there was a breed of sheep peculiar to this formation. The hills of Buckinghamshire are situated on the same broken, bluffy land, wooded with beech. The general characteristics of the soil are pretty much like those of the Calcareous Grit and Coral Rag.

Purbeck Beds.—The Purbeck Beds have several distinct characteristics, one bed being a stiff clay, another a light-coloured fissile limestone, while the so-called "Dirt Beds" appear to be the remains of an old soil of a marly nature. This formation caps the hills at Swindon, and it can be understood that, as the formations vary, so also do the soils on the same. Thus we have them varying from stiff clay to marly limestone—the latter being physically a ferruginous, brown, brashy loam, with wooded hills and bluffs, on which the ash and elm flourish. Crimson clover does well on this soil.

The Liassic and Oolitic formations generally are characterized by alternate beds of calcareous and clayey strata, yielding belts of dry, rubbly soil, or of stiff clay. The middle part of England—a stripe running from Yorkshire to Somerset and Dorset—is composed of these, with a corresponding alternation of soils every few miles when examined across country from west to east, and with the crops coinciding with these "lithological belts," while there is a more remarkable coincidence in their effect on the natural forest timber.*

* **Page**: "Economic Geology," p. 36.

CRETACEOUS.

Hastings Beds.—The Hastings Beds consist for the most part of massive soft sandstones, of a yellowish colour, and easily weathered. The soil from the same is, of course, of a light nature—sand predominating—and in many parts it forms uncultivated heaths, poor and bleak, and unenclosed. The surface is undulating, the hills in Sussex rising to the height of several hundred feet. Within the term "Hastings Beds" are included a good many formations such as the Tunbridge Wells Sands, of fairly good quality soil, and the Fairlight Sands, which yield a nearly sterile soil. On the other hand, we have the opposite extreme in the case of the Grinstead Clay and the Wadhurst Clay—beds which occur in the Tunbridge Wells Sands, and are almost exactly similar to the Weald Clay, and yield a clay soil of a yellowish colour. The Ashburnham Beds, again, yield wet, stiff soil, so that it is necessary, in collating the soils to their respective formations in this district, to be exactly sure of the particular one we are studying, as the group contains such a wide variety of the same.

The sterility of the sand beds may be due to the presence of excess of iron ("iron-sand") while some of the sand is so exceedingly fine that it holds the wet like clay. This latter is overrun with rushes, and sheep are fed on it with difficulty.

Typically, the Hastings Sands produce a yellowish or brownish sandy loam, very weak, and naturally producing heath, furze, broom, and other brushwood, with larch forests. Under proper cultivation, however, it can be made to yield good arable crops, while a large proportion of it is in grass, and is kept up by sheep-feeding.

Horsham Stone.—This is a thin, fissile, shelly, calcareous rock, some of the beds of which are so full of encrinital fossils as to give the stone a variegated appearance all over when cut and polished, and forming what is known as Petworth "Marble." This is the material out of which Tenterden steeple has been built, as also the nave of Canterbury Cathedral. It weathers down to a light soil, as at Horsham, from where it takes its name, but its occurrence is so limited that it is not necessary to do much more than simply mention its name.

Weald Clay.—This is a bluish-grey clay, marl, and shale, which weathers down into a stiff, yellow clay, forming a tract of wet, tenacious soil, almost absolutely devoid of lime. It forms, on the whole, a flat plain—practically a valley when looked at in connection with the adjacent formations—and only some six miles wide.

Roads are bad on this formation from the difficulty of obtaining metal to make and repair the same.

Some of the parts are hilly, and the soil light, but clay prevails and is typical, and it forms essentially a wheat soil.* The gravel in the clay is sometimes cemented into hard masses with iron, and forms a kind of Ragstone, but is not the same as the special Kent Ragstone. The soil shrinks and cracks greatly in dry weather, in common with other clay soils, while near the rivers it forms wide, alluvial tracts of land, liable to be flooded. The principal timber is, of course, the oak, for which reason it also was sometimes called the "Oak Tree Clay" by William Smith† ; and, indeed, the name "Weald" means a wood in the old Saxon tongue, the name being given to the district in the olden days, when it was more or less one continuous forest, while "hurst" became a frequent terminal name after the Norman invasion, on account of these same forests. Curiously enough, some of the parts are hilly and composed of light soil, though an overwhelming proportion is of a clay nature, as described. It is very much benefited by draining and an application of lime in any form, the lack of lime being, indeed, one of the characteristics of the soil.

The soil and subsoil is of a fawn or hazel colour, and cuts, in ploughing, like a piece of soap ; but while unctuous and slippery it does not stick to the feet like the London Clay.

Atherfield Clay.—The composition of this formation is pretty much the same as that of the Weald Clay on which it rests, being a reddish dark-coloured clay with thin beds of calcareous matter. The soil formed from the same is very wet and stiff, and not at all suitable for arable land, being sometimes so "stiff and wet as to set the operations of ploughing at defiance."‡

In some places where the limestone is more plentiful, at its junction with the Greensand, it forms what is called "combe land," exceedingly productive for hops and fruit, and even grain.§ Where

* *R. A. S. E. Journal*, 1858, p. 182.
† Ibid., 1858, p. 186.
‡ Ibid., 1846, p. 279.
§ Ibid., 1872, p. 249.

the limestone predominates it is, of course, richer than the purely clay variety, though still of a stiff texture and a brown colour. As it is so wet in its nature it, of course, requires draining as the first improvement, while the lime beds associated with it generally yield a sufficiency of this material. The Punfield Beds and the Speeton Clay of Flamborough Head are practically varieties of this, and with similar characteristics.

Kentish Ragstone or Hythe Beds.—The material of this formation might be described as a calcareous sandstone, and is best known from its use as a whetstone for sharpening tools. This formation is the most important of the Lower Greensand, and it yields one of the most fertile soils in the South of England. This will be understood when it is stated that the typical soil of Kent—"the Garden of England,"—is situated on this formation and the soil formed therefrom. The Maidstone hop gardens are on Ragstone soil, and in particular, the Golden Hop, for which Maidstone is celebrated, reaches its best development on this ground, more particularly in the parish of East Farleigh—equally celebrated for fruit. The soil is stony, owing to pieces of rag and chert being liberally mixed with it, and where the sandstone is soft the soil therefrom is locally known as "hassock."* The soil is dry in most places, but in some cases the valleys therein cut down to the Atherfield clay below, and thus we find a line of springs along the junction of the two formations. Curiously enough, brick earth is found in this formation in various places, but it occurs in "pipes," in the same way that clay occurs in "pipes" in the chalk rock. Another example of this soil occurs at Coxheath—now enclosed. It was on a farm overlying this formation that a celebrated piece of draining was carried out at Knole Park, near Sevenoaks. A hollow-shaped stretch of ground required draining, and it was found that it would require an enormous expense to cut a leader drain through the edge of the "basin" to drain the interior part; but the owner—knowing something of geology—hit on the plan of sinking pits down through the superficial Lower Greensand strata to the Ragstone Beds, some 20 to 30 feet below. The land drains were all made to empty into this pit, and owing to the open nature of the Ragstone Beds, the water drained away through this hole, as through a bottomless well.†

---

* *R. A. S. E. Journal*, 1872, p. 251.

† Ibid., 1847, p. 34.

Folkestone Beds.—Lithologically these beds are greensands, equivalent to soft sandstone with some clay. They contain a certain proportion of lime, and are, therefore, fertile, as in the district between Ashford and Folkestone. If the calcareous matter is absent, then it forms commons and heaths, though these can be much improved by marling from the adjacent middle Gault.

The soil is always light in texture*—a reddish sand, as at Redhill, a ferruginous sandstone at Blackheath, Farleyheath, and also at Faringdon, in Berkshire. In juxtaposition to the Folkestone Beds occur the Sandgate Beds, which are clayey, wet, and spongy, forming a stiffish loam—though not so stiff as the Gault or Weald Clay—and yielding Fuller's Earth for commercial purposes.

This is an excellent soil, good for wheat, especially growing rigid straw ; the soil called "Gaize" being rich in soluble silica.

Lower Greensand.—The material of which this formation is composed is practically an iron-sand, more or less green in colour where it is unweathered, through the presence of the mineral glauconite—a double silicate of iron and potash. The soils formed from the same are not valuable, as they are really more or less of the nature of sterile sand, as at Horsepath, in Oxfordshire ; brown to yellow in colour, light, weak, hot, and very much given to being infested with the finger-and-toe disease where turnips are grown. It forms hilly ground, which protrudes up through the Gault in the Weald district, very light soils in Buckinghamshire, and red-brown, weak soil at Leighton Buzzard, the grass on the same being of a poor nature. Larch and pine are the typical timber, as at Sandy, in Bedfordshire, but there is an exception with regard to this point in the case of oaks which grow at Sevenoaks, in Kent. The typical nature of the soil is very sandy, poor, and sterile, and is very largely unenclosed common.

The Woburn Sands belong to this group, and are interesting as the formation on which the Royal Agricultural Society of England has established its experimental station.†

Where it is in arable culture sheep-folding is largely practised.

---

* *R. A. S. E. Journal*, 1872, p. 250.
† Fream : "Soils and their Properties," p. 136.

PLATE V.

Mountain Limestone: Cheddar Cliffs.

Chalk: Kingston Hill: South Downs.

The Gault.—This may be described as a calcareous clay, dark blue in colour and easily disintegrated. Though it sometimes weathers to a brownish colour, yet the soil is always "black land," on account of its dark appearance; always stiff and hard to plough —being three or four-horse land—though much improved by draining. The middle part of the Gault is marly in nature, and often dug for manurial purposes, while the surface is mostly in grass*; indeed, the soil may be taken as quite unsuitable for arable purposes, from its sticky nature when wet. It is considered one of the stiffest soils in England, and is therefore best in grass, and, indeed, will seed itself if the arable land is let alone.

Alice Holt Wood is the greatest elevation of the Gault formation in England, and there it is a yellow, wet clay.

In Surrey exceedingly fine oaks grow on this soil, also elm and ash, but the oak may be taken as the special tree of the same.

The land is all in grass in the dairy district of Tetsworth, and other places in Oxfordshire, while, unfortunately, the pasture is somewhat given to the growth of Tussac grass *(Aira cæspitosa)*, a grass which is considered to indicate a large quantity of soluble silica in the soil.†

In the Isle of Wight the Gault is known by its damp and rush-grown soil—all in pasture.

There are no springs or water supply to be found in this formation, and farms have consequently to depend upon pond water; and, therefore, while some fine pasture land is to be found on the same, it is not at all a desirable soil on which to farm in any case. The Gault, indeed, is the basis of one of the great clay soils of England. White, of Selbourne, said that the Upper Gault is simply a rank clay in Hampshire, and in some districts it goes under the name of "malm" soil or the "black malm" of the Lower Gault. It forms a dark clay soil in Oxford, good for elm trees, apples, and beans, but it is mostly in grass and laid out in the old-fashioned high ridges—a relic of the days when high-priced corn was grown, and before the invention of land draining. It forms a depression everywhere at the foot of the chalk escarpments, as it has weathered down and been washed away so rapidly in bygone ages. At Culham it is indistinguishable from the "Kim" clay.

---

* Woodward: "Soils and Subsoils of London and Neighbourhood," p. 25. *Mem. Geol. Sur.*

† McAlpine: "Grasses," p. 19.

The Vale of the White Horse, in Berkshire, is the most productive district on this soil, while in the poorer parts there is a superabundance of ant-hills on the surface. It is essentially a grass land formation, and yields rich herbage in the above Vale.

Where, however, the drift from the chalk hills mixes with it, we have (as is usual with mixtures) a better soil, and in the Vale of Ringtale there is a good example of this fertile admixture. In the olden times this was celebrated for its wheat and barley, making the best " mault " in Queen Elizabeth's time, so that she boasted of her " Hitchin grape." Hertfordshire was then famous for white flour, though the Vale of Ringtale is better adapted to the coarser red wheats.*

Upper Greensand.—This is a soft, glauconiferous sandstone, intermingled with calcareous deposits, and yields a soil of great fertility. In the deeper subsoil it is greenish in colour, owing to the large amount of glauconite present, and contains much soluble silica, as met with in the soils on this formation in the Isle of Wight, and also at Farnham, in Kent—celebrated for "Whitebine" hops—where it mingles with the chalk formation. It is, indeed, one of the great hop soils, a fact that is exemplified by the extraordinarily luxuriant growth of wild hops at Easington, in Oxfordshire, at the junction of this formation with the Gault, and at Milton Hill, in Berkshire.† It forms a good, malmy or rubbly soil, and is one of the best, if not *the* best of the lighter class of soils to be met with in England. Chidham wheat yielded good returns on this soil when it failed on the clay. It contains nodules of phosphatic material (coprolitic), and, curiously enough, the same occurrence of phosphatic material is met with from Orel to Saratov, in Russia, and also at Samorode, in France. The formation weathers down to form land more or less level or slightly undulating, of a drab colour, and, from the amount of soluble silica present, it also is known as a " Gaize " soil.

Where the chalk partly mixes with it there is a strip of very fertile ground, but where the black sand and the white, silvery sand predominate, the soils are exceedingly poor, producing nothing naturally but heath.

The typical deposits are mostly all under cultivation: in Devon and Dorset, for instance, the rich, tender, brown loam is called

* *R. A. S. E. Journal*, Vol. XXV., p. 315.

† Ibid., 1860, p. 12.

"fox-land," and is very fertile.* As it forms a long, narrow strip between the Chalk Marl on the one hand and the Gault Clay on the other, it has often been improved in the olden time by carting loads of either material on to it as a top dressing, while deep or double ploughing has increased its capabilities.

Chalk Marl.—The soil of the Chalk Marl is also one of the most fertile of all the lighter soils to be met with in England, and the most productive of the chalk group.† It is a soft, light, grey marl with much soluble silica present, and also a certain proportion of glauconite. Being in its solid parts a calcareous rock it is sometimes used for marling, and when in this process it is exposed to the air for some time it falls into a grey powder. It forms the most productive part of the Wealden area in Kent—exceedingly fertile in character. In a similar area in Hampshire the soil is known as "malm," and if we cross the Atlantic we find that the prairies of Georgia are composed of the same sort of soil, on which the famous Georgian wheat is grown. Both in England and in Georgia the soil is dry, on account of the natural drainage through the subjacent rock. The herbage is close and sweet, and in both regions water is exceedingly scarce, and has to be obtained by artificial means during the greater part of the year. In short, wherever this soil appears it has the character of being an exceedingly fertile and productive variety, and in England, at least, the greater part of it is in cultivation, with comparatively little in natural pasture.

Lower Chalk without Flints.—To those who would naturally expect that the soil derived from chalk would be of a white and calcareous nature, it comes somewhat as a surprise to find that the typical soil of this formation is a reddish-brown clay to loam, with some whitish soil showing only in places. When we come to study the mode of formation of this soil, however, the puzzle is solved. Chalk contains naturally from 2 per cent. to 6 per cent. of earthy matter, and it is this small percentage which, by accumulation, forms the red or brown soil. The chalk itself wastes away by the dissolving action of rain containing carbonic acid gas, and in the course of ages, where a surface of this formation has been exposed,

* Morton: "Nature and Property of Soils," p. 40.

† Topley: "Agricultural Geology of the Weald," *R. A. S. E. Journal*, 1872, p. 244.

the chalk itself has literally all been carried away in solution, leaving this small residue to collect and form a brown, loamy soil. On the downs or hills the soil has practically not collected at all, as it has been washed away by the downward run of the rain-water, and consequently there is very little earth, and what there is is more or less disintegrated chalk—forming "white land" on the slopes and hills, exceedingly suitable for sheep-walks on account of the good though thin grass that grows on the same. (Plate V.)

Many of these chalk hills are covered with flint gravel, possibly the remains of the denuded Upper Chalk, as on the Dorset Downs, the gravel being 20 feet deep at Buckland Newton. This, of course, forms a naturally weak soil, but where well farmed, as in West Norfolk, it gives good returns. Some of the fields have apparently no soil at all, but only a mass of flints in the "dry valleys"; but these serve as shelter and warmth, and crops grow well.* The beech tree is the timber especially peculiar to this formation, and on the Chiltern Hills the beech is a regular "weed," springing up naturally everywhere; while in the Eastern Counties, the "pasque flower" *(Anemone pulsatilla)* grows on the dry chalk banks, and also in the combes—as at Barton, in Bedfordshire, on the south-west slopes. The box also grows well in some districts, as at Box Hill and Boxley (which take their names from it); and the yew and juniper are plentiful on the Sussex Downs, along the old "Pilgrim's Way" from Winchester to Canterbury—the scene of Bunyan's *Pilgrim's Progress*. On the same Downs the wild thyme is plentiful, and is believed to beneficially affect the flavour of the South Down mutton, while gorse grows in 30 to 40-acre patches.†

There are no springs on this formation, with a consequent scarcity of water, and a liability of the soil to burn in drought. It makes rather an inferior pasture in the natural state, bones being of very little use, though nitrogenous manures are beneficial.

It is necessary to draw a distinction between the soils formed from the Chalk alone, and those from the Chalk-with-Flints. Unfortunately the Geological Survey Maps do not show the distinction between the various formations of the chalk series, but class three or four different ones together, and simply allow one colour (a

* Topley: "Agricultural Geology of the Weald." *R. A. S. E. Journal*, 1872, p. 245.

† Martin: "Sheep," p. 13.

light green, lettered h^5) for the lot. In the most recent maps there is an attempt made to show by figures where the various beds form the surface, but as the outline of each is not indicated, the result is of very little use to farmers or others interested in land. The most of our chalk hills or downs belong to this "Lower" formation, and are generally classed as inferior chalk lands in contradistinction to the soils yielded from the Upper Chalk. To put the matter generally, the Lower Chalk forms the various Downs, the home of the Kentish and other Down sheep, and such barren stretches as Croxton Heath and Thetford Warren in Norfolk, and Cranborne Chase in Wiltshire. The Lincoln Wolds have some "drift" on them, so that their soil is modified, and forms good arable land in places. The Upper Chalk-with-Flints yields good loamy soil, while, of course, the Chalk Marl is one of the best of this medium-textured class of soils in England.

The comparative value of chalk land generally, however, may be judged by the fact that the lowest-rented counties in England are on these formations.*

Upper Chalk-with-Flints.—This group is one of the most productive of all the chalk soils, and one of the lighter kinds. It forms a good brown loam, rather more tenacious than the soil of the Lower Chalk, though in the neighbourhood of Ramsgate, in the Isle of Thanet, the soil is of a light, loamy character, from 12 to 24 inches thick over the chalk rock.

It gives good results where irrigation is practised, so that good water meadows are found on this formation—more particularly in Wiltshire (as at Andover), and in the ravines of Salisbury Plain, and also at Downton Agricultural College.† Crimson clover, lucerne, sainfoin, and trefoil are all largely grown, as the common clovers fail on these soils, while all kinds of arable farming, root growing, and sheep folding are practised. The contour of the country is generally undulating, in some parts of a plateau nature, as on part

* Johnston: "Agricultural Chemistry and Geology," 17th Ed., p. 114.

† Risler: "Geologie Agricole," Tome II., p. 199. "The manor is in the valley of the Avon, of which the alluvial ground, with the gravelly subsoils, have been formed partly by débris of the tertiary formations which are deposited on the left bank, in the New Forest, and partly by the chalk which crops out on the right bank, in the surrounding downs, and extends towards the north up to Salisbury Plain."

of Salisbury Plain; while the soil shows a brown, earthy to clayey texture; at other places, where the chalk shows through, it is even "white land."

Water is scarce on the higher grounds, as with all other chalk formations, and deep wells have to be sunk to get the same. Even in the chalk district of Alabama the same state of matters obtains, and the farms there are large because only farmers of large means can afford the deep boring necessary for a good water supply.

Between Chinnor and Goring the white wheat straw grown on this soil is exceedingly suitable for plaiting for hats and other goods, while in the neighbourhood of Luton, Dunstable, and Hitchin the straw-plaiting industry is largely engaged in, owing to the quality of the white wheat straw there grown*; though the straw is short the corn is of good quality. Risler says that the plateaux of this formation form the "Champagnes of England." The fields are generally unenclosed, and thus the country is much exposed in these regions—a contrast to the farming on many other formations †; while sheep folding is almost universal, both in its east and west outcrop, as in Norfolk and Wiltshire, it being one of the best barley soils. Field mustard is the predominating weed, while farm-yard manure, bones, and superphosphate have almost magical effects.

* Elsden: "Agricultural Geology of Herts," p. 157. *Trans. Herts Nat. Hist. Soc.*, 1883.

† Morton: "The Nature and Property of Soils," 4th Ed., p. 36.

CHAPTER VIII.

FORMATIONS AND FARMING.—III.

TERTIARY OR KAINOZOIC.

EOCENE.

Thanet Sands.—This formation is the lowest of the English Tertiaries, and is mostly confined to Kent, Surrey, and the south-east corner of England generally. It is typically developed in the Isle of Thanet, from which it takes its name; and the fields between Pegwell Bay and Minster, Ebsfleet Farm, and the green knoll of glauconiferous sand on which Richborough Castle stands—the historic ground where the Romans, the Saxons, and St. Augustine landed—and overlying the slope of chalk uplands to the north—are typical examples of the soil. It may be described as a good sandy loam, all in cultivation, fit to grow anything, easily worked and early, and of a dark-brown colour. It is a soil on which a chill-plough would do splendid work, but the huge-wheeled Kentish plough still obtains in the district. It seems to suit the growth of hops, peas, Chevalier barley, elm, and elder—the latter especially—while sainfoin and lucerne are favourite crops. Though not containing much reserve of fertility, it responds to applications of manure of various kinds, and is easily worked. Near Cliffe, in Kent—overlooking the Thames—there is another strip of the same formation with a sandy loam soil on top.

The Woolwich and Reading Beds.—These are described by the Geological Survey as consisting of "clays, sands, and pebble beds," and as they comprise the most widely spread of our Tertiary strata* they present many examples of variation and structure. The principal beds consist of massive mottled clays with subordinate laminated clays and intercalated sands,† but the clay predominates to such an extent that this group was known to the older geologists under the general name of the "Plastic Clays"—the "*Argile Plastique*" of the French geologists.

---

* Prestwich: "Geology," Vol. II., p. 340.

† Ibid., p. 343.

As the name indicates, the surface soil is a dark-brown or reddish, sticky, unworkable clay, mostly in grass, and of such a nature that a brickwork might be started almost anywhere, the subsoil being of every sort of colour. The deposit underlies practically the whole of the London and Hampshire Basins, showing itself in an outcrop about 10 miles wide at the most all round the edges of these, the surface ground being by far the most obdurate and intractable that is found in Britain.* "The viscous tendency is extreme, and binds the whole mass into large lumps, which defy the power of most implements either to pierce or reduce them." The surface conformation is generally flat, interspersed with gentle eminences, and mostly in grass. Farm-yard dung in a half-rotted state, and ploughed in, is almost the only manure that gives any results; and though soot or nitrate of soda applied in spring give good effects, it may be said that artificials generally are of little use. Indeed, the farming is usually similar to that on the London Clay, with which its deposits are often intermingled.

Drains require to be put in very closely together and very shallow—12 to 15 feet between the lines of pipes, and 2½ feet deep—in order to give the best results, and even then it is sometimes necessary to work the arable land in narrow ridges or "stetches" to facilitate surface drainage.

Where this "Plastic Clay" comes into contact with the top of the chalk, an improved soil is produced; mixtures of any sort being generally better than single-origin soils. Thus, this mixed soil at Ware, Bishop's Stortford, and neighbourhood, produces some of the finest barley in the three kingdoms, and fetching the highest prices.†

But where the sands and gravels come to the top it forms a wet, hungry soil, as in the neighbourhood of Hatfield. Arthur Young, in his farming days, occupied a farm on this formation at North Mimms, near Hatfield, and this is what he wrote of the soil:—"I know not what epithet to give it: sterility falls short of the idea—a hungry, vitriolic gravel. I occupied for nine years the jaws of a wolf. A nabob's fortune would sink in the attempt to raise good crops in such a country."‡ No wonder his farming was not a

* Donaldson: "Clay Lands and Loamy Soils," p. 56.

† Johnston: "Agricultural Chemistry and Geology," 17th Ed., p. 115.

‡ *R. A. S. E. Journal*, 1864, p. 271.

financial success, though these sands and gravels are capable of improvement by chalking.

The oak grows well on this as on other clays, and in Dorset, where the outcrop is not more than a mile wide, its direction is shown by a strip of oak timbering across the country.

The intercalated "sands" sometimes contain masses of sandstone formed by infiltration of siliceous cementing material, and which thus make solid blocks of hard stone. Where the beds have been weathered away these stony masses are left, and thus on the chalk downs and adjoining areas they are found on the surface like erratic boulders, and known as "Grey wethers" or "Sarsen stones." These sometimes come in exceedingly handy for farm purposes, for road-making, building stones, gate-posts, paving stones, &c., and the prehistoric builders of Stonehenge—whether Druidical or otherwise—found most of the stones for the same from this formation without going very far away.

Oldhaven Beds.—These are almost wholly restricted to a very small strip of country and a few isolated knolls, between Oldhaven "Gap," near Reculvers, and Herne Hill, all in Kent, and are of only limited interest agriculturally. As they, however, have a decided influence on the nature of the fields which lie thereon, it is necessary to notice what this influence is. They include the "Basement Bed" of the London Clay of some geologists, and consist of a series of sands and gravels, yielding a light, friable soil—the sands sometimes being glauconiferous. A typical example is Sandhills, between Faversham and Graveney. The surrounding level formations are Woolwich Beds, yielding a stiff clay soil, mostly in grass; the body of the "hill" is Oldhaven sandy loam, all arable, and formed of a friable soil; while the summit is capped by London Clay, in grass and timber. Indeed, the grass on these London Clay knolls is so much better than that on the lower ground and on the alluvial marsh land of this neighbourhood, that they stand out green when the latter is only covered by brown, withered "bents."

At Hassenbrook Farm, near Stanford-le-Hope, in Essex, a small, thin patch of this formation occurs, largely composed of rolled flint pebbles in sand; but it is the best strawberry land in the district,* while it is noteworthy that strawberries are also largely grown on this soil in Kent.

* Jerome-Harrison: "Geology of Counties of England and Wales," p. 88.

The London Clay.—The London Basin is a name given to a wide area of land round the metropolis, and which, together with part of the same formation in the Hampshire Basin, at one time must have been the site of the estuary of a mighty river flowing eastwards. The estuarine mud deposited from this water now forms the deposit of the London Clay with its associated formations, and the lithological nature of the same is best described as a bluish-grey clay, weathering to brown on exposure. This blue colour is due to the presence of carbonate of iron (a protosalt) which weathers into the brown peroxide.* The brown colour extends downwards pretty deeply, and it is only in the case of deeper excavations that the blue-grey part is reached. The soil is a tenacious, sticky, cold clay—"as it absorbs a considerable amount of moisture"†—largely in grass, and requiring much fallowing and cultivation to enable it to grow good crops. It seems to be wholly clay in its composition, with a very small proportion of very fine impalpable micaceous and siliceous sand, and some oxide of iron.‡ It is less waxy and slippery than the "Plastic Clay," but fully as obdurate and intractable in the management, for "its tenacity is very great and a little rain makes it work like mortar. In the wet condition it is not slippery, but adheres to the feet; in dry weather the firm land opens into chinks that are both wide and deep. In an arable condition, the soil, when the least damp, is pushed before the breast of the plough and falls from it in large lumps; while in dry weather the hardened masses most obdurately resist the action of any implements of mechanical power. In the dry months of summer the harrow and the roller are not able to produce any impression on the hardened clods of the fallowed ground, till the approach of autumn introduces a cooling influence and a crumbling effect, when the land falls into a friable mould, which is produced by the relaxation of the baked condition of the soil by the heat of the sun. On this pulverized soil, lime or farm-yard dung are spread and ploughed under by the swing plough, and the land is ready to receive the seed (wheat) in October."§

* **Jerome-Harrison**: "Geology of Counties of England and Wales," p. 173.

† **Woodward**: "Soils and Subsoils of London and Neighbourhood," p. 25. *Mem. Geol. Sur.*

‡ **Morton**: "The Nature and Property of Soils," 4th Ed., p. 23.

§ **Donaldson**: "Clay Lands and Loamy Soils," p. 63.

In the days when wheat was worth over 50s. per quarter, this soil, on account of its nearness to London, was valuable for wheat-growing purposes, and wheat, clover, and beans were the principal crops, with an occasional fallow when the land became foul; but since the advent of the "depression," the produce has failed to pay expenses, and much of such land became "derelict" and lapsed more or less into a state of nature.* On farms where there is a large proportion of permanent pasture it is possible to introduce other forms of farming—such as dairying—and thus keep them going; while the proximity to a station has a great influence on the farming value, as elsewhere. Lime and dung in all forms are the most efficient dressings, while of artificial manures basic slag on pasture has had the most noteworthy results; dressings of many of the other artificials having been literally thrown away. On the other hand, the soil seems to contain so much "body" of itself —*i.e.*, a reserve of fertility—that it only needs efficient cultivation to bring it out. Indeed, the practice of the native farmers is simply to keep the land clean by perpetual cultivation and occasional fallowing, with an application of such dung and lime as is easily procured, and an endless succession of good crops may be produced.

So special and suitable is the soil for grass, however, that in north Middlesex such a clear line of division exists between the London Clay soils and the gravelly loams over the Chalk that the boundary can in many places be traced by the sudden termination of the grass land and hay farms, and the change to arable land.†

The teazle grows well on this clay, and the uncultivated plant is a conspicuous object along the edges of the ditches or other waste damp spots.

The oak and the elm flourish, and there are many magnificent specimens of each to be met with.

In many parts there are beds of marl interspersed, belonging to the Chalky Boulder Clay, and in former times this was dug out and spread over the fields, with beneficial effect. These "clay-pits" still exist as ponds, which are now handy as a source of water supply for the use of stock, for there are no springs on this formation.

---

* Pringle: "Royal Commission on Agriculture: Report on Essex Districts," 1894.

† Elsden: Agricultural Geology of Herts," p. 154. *Trans. Herts Nat. Hist. Soc.*, 1883.

The greater part of the author's farm is situated on this clay, so that he has learned from sorrowful experience what the nature of the soil is. Tiptree Hall—farmed by the late Mr. Meechi—is also on this soil, and is now a fruit farm.

The rest harrow (*Ononis arvensis*), the water-grass agrostis (*A. stolonifera nigra*), and the field foxtail or black grass (*Alopecurus agrestis*) flourish among the weed tribes on this soil, while the number of ant-hills on the pastures is remarkable.

The general contour of the land is a low, uneven, gentle, undulating surface, the highest land not much over 400 feet over sea-level, though some few hills in Essex reach 600 feet. (Plate VI.)

Lower Bagshot Sands and Gravels.—The soil formed from the débris of this formation is of a sandy or gravelly nature, and as it occurs mostly in patches on the top of the London Clay it forms fields of lighter soil, breaking up the area of stiff clay in the district round the metropolis. Farms on this soil are suitable for growing roots and forage for sheep folding, whereas the stiff soil over the hedge may render this system of farming very precarious. In some spots, of course, the soil may be too sandy or gravelly to be fertile, and thus form a "common"; but as a rule—while it has not the "body" of the clay formation—it is more easily and satisfactorily worked.

Bracklesham Sands.—A sandy formation in the same district as the above, forming a light soil—"not bad working land"*—of somewhat better quality where mixed with the clay of associated formations. Woods and wastes cover a small portion of the same, but mostly regular plantations of larch and pine.

Barton Clay.—Of very limited extent in the New Forest area at Barton Cliffs, and on the Isle of Wight opposite. The Clay formation predominates, forming a poor, stiff soil. In its original state it is blue, but becomes yellow when weathered, like many other blue clays. It forms the oak and timber soil of the New Forest district.†

---

* *R. A. S. E. Journal*, 1861, p. 269.
† Ibid., 1861, p. 251.

Upper Bagshot Sands.—As the name indicates, these are simply a series of sands—agriculturally of a very poor nature. It is sufficient to mention that they form the surface at Bagshot, Aldershot, and Sandhurst, to indicate the poor, barren, moory nature of the surface accumulations; a little peaty soil in the hollows, on which grass never grows; and plenty of heath, broom, and birch about, with the Scots and other pines for plantations. This formation is the basis of many of the "heaths," "commons," and "moors" in the neighbourhood of the metropolis—though not all of them—and is, perhaps, one of the most barren soil formations—excepting only drifting sand—in the United Kingdom.

OLIGOCENE.

Fluvio-Marine Series.—Underlying the New Forest and that part of the Isle of Wight which is opposite the same, there are a series of beds of clays, marls, and gravels which are known by the names of the various places where they are found. The Geological Survey recognises three groups, to each of which is allotted a colour on the maps; this being an instance of minute subdivision quite unnecessary for farming purposes, as on the other hand the Chalk is not subdivided enough. These beds are known in descending order as:—

(1.) The Hempstead Beds—marl and clay.
(2.) The Bembridge Beds—green marls and sands, shales, and limestones.
(3.) The Osborne and Headon Beds—green marls and grey and red clay.

These formations resemble one another in their lithological characters, and consist of a succession of marls, clays, and limestones, yielding a cold, wet, poor soil where they come to the surface. The Hempstead Beds, in particular, form a poor soil; unreclaimed wastes, pasture and woodland. The Headon Beds, however, afford the best land in the New Forest, where not covered with gravel.* In this area they are partly overlain with chalk-gravel washed out of the Wiltshire chalk hills on the north, when an Eocene

* *R. A. S. E. Journal*, 1871, p. 241.

sea flowed over this locality. The ancient chronicles asserted that William the Conqueror, in afforesting this region, evicted a prosperous rural community and allowed a fertile district to return to a state of nature. It is quite impossible that he ever could have done so, for "no wheat could ever be grown on this great bed of chalk-gravel, which is varied only by patches of sand."* It is simply a region which naturally grew timber and copsewood, and was never valuable enough to be reclaimed for farming purposes, and the Conqueror would cause very little disruption of rural communities in making it a "royal chase."

MIOCENE.

Lenham Sands.—Geologists disagree about the existence of any Miocene rocks in Great Britain. Some hold that the lignite and leaf beds of Bovey Tracey and the leaf beds of Mull are of this age, as also the Lenham Sands, while others affirm that this system is totally wanting in our Islands. Anyway, these special formations are of no agricultural importance with us—the beds at Bovey Tracey forming on the surface only a stretch of alluvial, peaty land. It is generally believed that the basaltic plateau of Antrim and of the Western Islands is of this age, but basaltic formations have already been discussed. On the Continent, however, and especially in France and Switzerland, formations of this age form vast regions of great importance as surface formations, influencing the farming, scenery, and the physical features of these regions very much.

These take the form of marl and "molasse" (marly sandstone), and yield some of the finest soils to be met with abroad.

The vineyards of the Uitliberg at Zurich are dressed with this "molasse,"† while the Emmenthal—celebrated for its cows and its cheese—owes its fertility to this same formation material.‡

* Wise: "The New Forest," p. 237.

† Risler: "Geologie Agricole," Tome III., p. 11.

‡ Risler: "Geologie Agricole," Tome III., p. 19.—"Dans l'Emmenthal, une des plus riches vallées de la Suisse, célèbre entre autres par le fromage que l'on y fabrique, on trouve beaucoup de terres formées par la décomposition de la *mollasse*."

PLIOCENE.

Crag Formations.—Along the coast of Norfolk and adjacent parts there occur several local formations, which, though very small in extent, have proved of great value from a geological point of view on account of the contained fossils. These beds are classed as follows in a descending order:—*Forest Beds, Chillesford Clays, Norwich (Mammaliferous) Crag, Red Crag, and White (Coralline) Crag.* Though of so great importance geologically, they have little agricultural significance; partly from their limited extent, and partly because they are mostly buried under deep accumulations of drift. In the words of Ramsay:—"They play a very unimportant part in the physical structure of England, occurring as they do in a few small, shelly patches of insignificant thickness in Norfolk and Suffolk. . . They do not at all affect the scenery,"* so that they may be almost dismissed with this notice.

Where they do show up near the surface they form sandy hills, with pines, and birch, and beech, while in the river valleys round Norwich, where the "drift" is cut through, they show a dark purplish loamy soil, with beech as the predominating tree, and stunted oaks; but "on the whole, the Norwich Mammalian Crag is of little agricultural importance."†

---

* Ramsay: "Physical Geology and Geography of Great Britain," 3rd Ed., p. 133.

† Trimmer: *R. A. S. E. Journal*, 1845, p. 459.

CHAPTER IX.

FORMATIONS AND FARMING.—IV.

QUATERNARY OR POST-TERTIARY.

POST-PLIOCENE OR PLEISTOCENE.

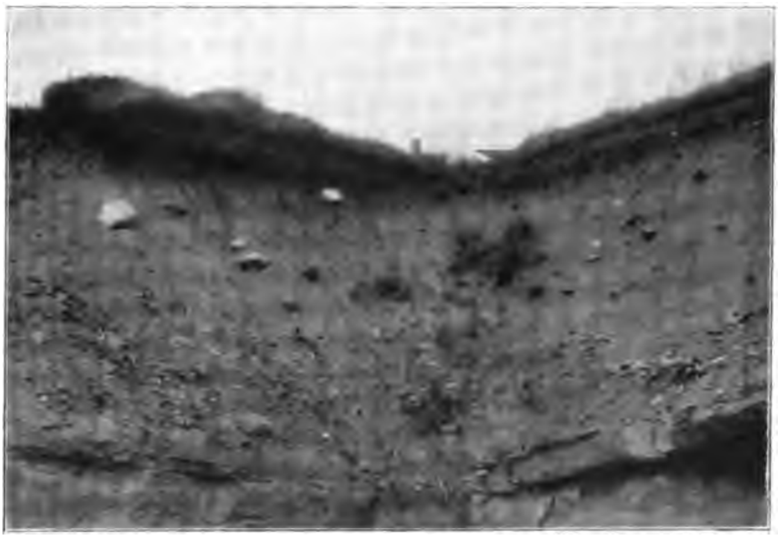
AT the close of the Tertiary Period at least the northern parts of Europe and North America were visited by a period of intense cold, resulting in the covering up of these regions with a sheet of ice, or a succession of glaciers, similar to the state of matters in Greenland and other Arctic regions at the present day. There appears to have been two of these cold periods with a more genial time intervening, while the last disappearance of the ice is variously computed to have been from 7,000 to 10,000 years ago. As the result of this fluvio-glacial action, the original features of the country have become very much modified in some districts, and a large number of formations or beds were laid down—forming the greater part of the "regolith" of Merrill—and from which a large share of the surface deposits of the country have been derived. These differ widely in nature, but for our purposes they may be classed as follows, taking them in chronological order as far as possible :—

1. Lower Boulder Clay or Till.
2. Interglacial Sands, Gravels, and Clays.
3. Upper Boulder Clay or Till.
4. Post-glacial Sands, Gravels, and Clays (the "Glacial Drift").
5. Boulders and Erratics.
6. Moraines.
7. Kames, Eskers, &c.

The last four of these are simply different varieties of material formed and deposited by the action of the receding ice, and of the water resulting from the melting of the same ; while, where part of the affected regions were under sea-level, the sea-action modified

PLATE VI.

London Clay, Arable and Pasture Soil: Essex.



Boulder Clay, deposited over Carboniferous Shale and Sandstone: Auchinleck, N.B.

them somewhat, their formation and deposition being more or less coeval with one another. As some of them have distinct agricultural or rural characteristics, however, they will be taken separately as far as necessary.

At the same time it must be pointed out that as these are all related to one another, and, partly at least, contemporaneous in deposition, they merge into one another in many cases, and it is not always easy to draw the line of demarcation.*

In the classification of the glacial deposits above given the Lower and the Upper Boulder Clays or Till are agriculturally very much alike. The Lower is harder and tougher than the Upper, while the Upper has some tendency to rough stratification. These divisions, however, are not recognised by many English and American geologists, as they hold that there was only one Ice Age; that the Lower Till was formed during the growth of the ice covering, and the Upper during its recession; that the latter owes its characteristics to being more exposed to denudation and weathering since then, while being more loosely laid down originally; and that the sands, gravels, eskers, &c., were formed in the final wind-up of a fluvio-glacial state of matters. Even Geikie (Sir A.) has stated in one instance, regarding a locality known to the author, that "though it is possible to recognise that there is a stiff Lower Boulder Clay and a loose, more gravelly, Upper Boulder Clay, these cannot well be separated in mapping."† Agriculturally they may be taken together as—

The Boulder Clay.—First, as to the composition of the same. The Boulder Clay varies from a dark, slaty-coloured, indurated clay (Till) to a light-red or yellow and friable variety, without any bedding, but full of water-worn and subangular stones of all sizes—from pebbles up to boulders weighing tons—mixed throughout the clay without any arrangement. The erratic boulders which are strewn over the surface of some districts, and which will be noticed later on, are practically part of the same series of formations, being, as it were, the final stage of the Upper Boulder Clay; but in the soil and subsoil there are embedded millions of these stones as well, and which are a constant source of annoyance on arable fields in such districts. No matter how often the horses

* Ramsay: "Physical Geology and Geography of Great Britain," 3rd Ed., p. 160.

† *Mem. Geol. Sur. Scot.*, Sheet 15, p. 38.

and carts or sleighs are sent round to collect the loose ones on the surface, there is a perennial crop of them, so that the clearing has to be constantly repeated, and country folks get to believe that the land "breeds" stones. The explanation is that in the top foot or two of soil and subsoil there is an almost exhaustless supply of these stones within reach of the frost. Every time the ground freezes it is heaved up a little, stones and all, and when the thaw comes it drops down again, but the earthy material sinks partly below the stones, so that these are raised a little every freezing and thawing, and thus eventually work to the surface. Those within reach of the plough and the cultivator are more quickly brought to the top, and the crop of stones will continue until all those within reach of the frost are removed—a process which may take years to accomplish—finality never being attainable in many cases. I have seen fields being reclaimed in Massachusetts, where the stones were as great in bulk as the soil. The soil left behind was a brown loam of great fertility, but the making of this soil arable required the removal of thousands of tons of angular blocks and boulders.

It must be distinctly understood that the Boulder "Clay" is not always a clay formation, for it may actually be sandy in its nature if derived from a sandstone source. In the case from Massachusetts, above cited, it forms a light loam of a brown colour, while over the Red Sandstone formations, for instance, it forms a red sandy accumulation, with a soil of the same nature on the top—as exemplified in the southern reaches of Nithsdale, the Lothians, the Vale of Eden, and parts of the Northern Midlands of England. This arrangement of formations is apart and distinct from the "Intermediate Sands and Gravels," and, indeed, is one of the puzzles connected with these deposits, and has given rise to no end of theorizing and disagreement among geologists. If the whole of the pre-glacial accumulations were swept off and a new lot brought from a distance and shot down in their place, it is remarkable that the material found in a given spot is now manifestly composed of débris identical or similar to that of the subjacent strata, or of strata a short distance further up on the higher land. The facts of the case are, that while in the northern parts of America the Great Ice Age must have been on an almost inconceivably large scale, in the British Islands everything was comparatively small and local even at the most extreme period; while, as it is acknowledged by all that the final wind-up of the epoch was characterized by the

existence of small glaciers in every valley radiating from the higher centres of the country, then the surface formations have been deposited as the débris of rocks a few miles off at the most. On no other hypothesis can we explain the fact that the "regolith" exactly follows, and is influenced by, the underlying formations, so much so that the "solid" geology is often a wonderfully exact indication of the accumulations above, and the outcrop of the various strata can be followed in the soil of the fields. Such indications, of course, are not universal, and it is not difficult to find instances where one deposit of Boulder Clay covers many different strata—especially so in the Scottish coal-fields—but they are sufficiently numerous to warrant us in adopting the principle as a guide. Perhaps the extreme case of distances travelled is where the mica-schist and gneiss of the Highlands has been carried as far south as Lesmahagow; but, on the other hand, the Till of the Southern Uplands of Scotland is from the contiguous hills.* (Plates IV. and VI.) (Map.)

Geikie (Sir A.) has long ago pointed out the relation between the *colour* of the Boulder Clay and the rocks of the districts adjoining the deposit—as indicating transport. Home, again, says, "The main mass of the Boulder Clay, in the basin of the Forth for instance, consists of comminuted débris of the carboniferous and other rocks which form the framework of that district. We can also gather that this loose, fragmentary material has been moved there from west to east. In the upper part of the basin of the Firth of Forth the coal-fields are covered with *red* Boulder Clay, abounding in fragments of the rocks which lie towards the north-west, and deriving its prevalent tint from the waste of the Old Red Sandstone which stretches up to the foot of the Highland mountains.

"The late Hugh Miller had previously pointed out how the pale Oolitic rocks of Brora and Golspie are covered by a *yellow* Boulder Clay, and the flagstones of Caithness are covered by a Boulder Clay of a *grey*, leaden colour. So, also, Mr. Cumming showed how, in the Black Isle (Cromarty), the Boulder Clay has the colour of the *red* rocks there, whilst to the westward the colour changes to a tint in correspondence with that of the slaty rocks. The same author points out how, in the Isle of Man, the colour of the Boulder Clay is *blue* near the limestone rocks and *red* near the

* Geikie (J.): "The Great Ice Age," p. 73.

Old Red Sandstone rocks. . . . . . These views are important, as they tend to prove that the Boulder Clay itself has been derived chiefly from the rocks over or near which it lies." *

Again, Geikie (Sir A.) points out that "the coarse, stiff, stony material differs in colour and composition locally, according to the nature of the rocks of each district. Among the Silurian hills (Nithsdale) it is dull grey or fawn-coloured, on the Old Red Sandstone tracts it is dark brown or red, while over the carboniferous areas it is of a black or dark leaden-blue tint."† There is no district where the Till deposit is more developed than in Ayrshire, for instance, yet the soil "follows approximately that of the geological formations beneath the surface."‡

Where the underlying rock is of a hard, indurated nature—as among the primary formations—its surface below the Boulder Clay will be smooth and polished or striated at the most; but where the softer rocks occur—as sandstones, shales, grauwacke, igneous rocks, &c.—the top will be a confused mass of broken blocks, slabs, and brash mixed with the clay of the Till. (Plate VI.)

Again, the Boulder Clay follows the same rule of deposition as river alluvium to a certain extent. It is much more coarse and stony in its nature up among the hills or at the top end of valleys, while it is more clayey and with fewer stones lower down the valleys, or on the lower grounds. Erratic boulders are more plentiful and more prominent on the hillsides than in the low country. The upper drift, composed more largely of water-worn material, is met with as high as 1,500 feet above sea-level in some places, while the Till does not form a regular covering above 1,000 feet, though patches of the same are found at a higher elevation in the south of Scotland.§

The term Boulder Clay is to a certain extent misleading, because while the deposits are generally of a clayey nature, they are not always so. The large proportion of clay in them is easily explained so far as this country is concerned, however. Bearing in mind the fact that during the greater part of the Ice Age—if not throughout the whole of that time—each of the higher ridges of

* Home: "On the Boulder Clay of Europe." *Trans. Roy. Soc. Edin.*, 1869, p. 660.

† *Mem. Geol. Sur. Scot.*, Sheet 15, p. 38.

‡ Ibid., Sheet 14, p. 27.

§ Geikie (J.): "The Great Ice Age," pp. 75 and 210.

the country was a centre from which glaciers radiated downwards in all directions—overtopping the smaller hills—it necessarily follows that the eroded material must have been derived from such centres. But a look at the Geological Map shows the fact that all the higher points are composed of the older and more indurated rocks, such as granite, dolerite, slates, schists, and so on—hills and mountains which, indeed, have been originally preserved because they are composed of old and indurated material which withstood the ordinary denudation that has been sufficient to wear the softer and newer rocks down to a lower and more even character; and as the débris of such minerals and rock material is always more or less of a clay of some sort, we may, therefore, expect the Boulder Clay to be more or less of this nature—at least near its source—where these old rocks predominate, as in the Highlands and Southern Uplands of Scotland. Again, in many of the newer formations there is a very large proportion of clays, shales, marls, mudstones, &c., all of which grind down into clay of some sort, as exemplified in the "Till" of the Lowland districts of Scotland, particularly of the coal-fields.

This clayey nature predominates all over the world in glaciated countries. In the Mississippi region, for instance, it forms a tough, impervious, and intractable subsoil, normally blue, but weathering to whitish or grey, and locally known as "hardpan," and forming the surface of the treeless plateau between the river ravines, "for hardpan plains are never wooded,"* as they either "bake" or "drown." Where the natural drainage is improved by the existence of more river cuttings, and the hardpan is thin, it weathers into better stuff, of a buff colour and friable nature, and forms a "fair or even excellent soil" for fruit or forest culture. The hardpan district occupies about 40,000 square miles in south-west Indiana, Illinois, and Missouri to Nebraska—thus forming a large slice of the drainage area of the Mississippi.

On the other hand, the Boulder Clay is not always a clay formation, as just mentioned, for it has been found that, even where it is apparently a clay deposit, and full of boulders, both the clay and the boulders form but a small proportion of its bulk. As a rule the stones and boulders (more than two inches in diameter) form only between 5 and 10 per cent. of the whole, while cases are rare

* McGee: "Geology and Agriculture," p. 14. *Trans. Iowa State Hort. Soc.*, 1884.

and local where they reach 20 per cent. Leaving these out, the remainder consists of the following proportion of materials :—

Gravel	... about	25	per cent.
Sand	... „	20	„
Rock-flour	... „	40 to 45	„
Clay	... „	12	„

This is the average of many samples, and this percentage of mechanical constituents is found to be wonderfully uniform. The "rock-flour" is, indeed, the most abundant and most conspicuous constituent, and which, as it looks like clay, and even behaves partly as such, has been taken for clay, and has thus given the name to the formation. It is, of course, the abraded material eroded by the grinding of the ice over a rock surface, and which is separated with difficulty by mechanical analysis from the clay proper; but under the microscope it is found to be largely composed of fine grains of quartz, and the material is thus often known as "quartz-flour." Its presence is a proof that a clay or other similar deposit is of glacial origin, and is a test of such. This component, being found in so large a proportion, accords with Daubreé's observation that the milky turbidity of the Rhine, even at a distance of hundreds of miles from the Alpine glaciers, is chiefly due to impalpable quartz.*

It is a noteworthy fact that the ordinary plastic clay of the brickyards on this formation contains not more than a fourth or a third of its weight of pure clay (kaolin), the remainder being mostly rock-flour.

It has been pointed out above that, in a surprising degree, the regolith follows the formations below. At the same time the transporting agent sometimes carried the débris of one formation down partly over the outcrop of the next, and mixed with the latter at the line of junction. The direction from which the transporting agent came being known, the direction of overlap is thus ascertained. In the accompanying diagram a section of such a country is shown where the distinctive regolith of each subjacent formation is pushed forward, as it were, a little over the next one—downwards. Agriculturally, the soil on a^1 is typical of the formation a, and so

* Crosby: "Composition of the Till or Boulder Clay." *Proc. Boston Soc. Nat. Hist.*, February, 1891, p 129.

of b^1 and b, while farms situated on the junction of the two have a soil intermediate between them. It is, in fact, just such an arrangement as this which is puzzling, if we accept the glacial theory, for if a great denuding agent like ice, or water with floating icebergs therein, was eroding the surface, one would expect to find all the different kinds of eroded materials mixed up, whereas each keeps distinct and separate in a surprising and even inexplicable degree, and this fact makes agricultural geology possible.

It may be pointed out, again, that as a further help to the study of surface accumulations of glacial origin, the six-inch Survey Maps (Geological) have two index marks to represent the "Boulder Clay" and the "Sands and Gravels": the former consists of a series of dots about a quarter of an inch apart all over the parts covered with the stony clay, and the latter of the same dots about one-

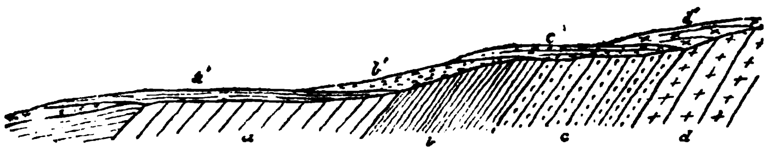


FIG. 8.

OVERLAPS OF BOULDER CLAYS OVER DIFFERENT STRATA.

eighth of an inch apart all over the parts where the gravelly soil lies. These maps are only issued, of course, for the coal mining or other rich mineral districts, but any one residing in such localities will be repaid by procuring the sheet for his district.

In studying the agricultural geology of a locality it is, therefore, necessary to take particular notice of these marks where they cover the deep-seated rocks, as they represent a stiff, stony soil or a sandy or gravelly one, as the case may be—of glacial origin—as the surface formation. "Drift" Maps are now being prepared and issued by the Survey, which are specially intended to show the nature of the surface accumulations, more particularly the glacial deposits. At the same time these must be studied with reference to the underlying rock and to the possible source of the material in the neighbourhood.

Normally, of course, the Boulder Clay yields a stiff clay soil full of stones, but it is a soil capable of yielding good crops when properly treated, and it is on this formation that some of the best farming of the United Kingdom is found. As an example of its producing power, the author may cite the case of oatmeal. The best oats for producing this are grown on the Boulder Clays of Ayrshire* and Midlothian; good meal may sometimes be produced elsewhere, but these two districts stand out pre-eminently in this line as regards their clay soils. The author could even cite the case of individual farms noted in this line, and also of farms in the same neighbourhood on lighter soil, where the meal produced is not half as good. It is possible, indeed, for one sample of oatmeal to be three or even four times better than another in feeding quality, weight for weight†—*i.e.*, taking the percentages of flesh-formers and heat-producers—for, to produce the best, a stiff soil and a moist, cool climate are necessary, and in Scotland the stiff soils are nearly all Boulder Clays from various sources. The much-advertised varieties of American oats are grown where the summers are hot and dry, and are not, therefore, up to the first quality. A good deal depends on the milling and preparation of the meal in making it palatable and fit to catch the public eye, but this does not alter the fact that one handful of oatmeal from one district will make as much porridge, and fill a man for as many hours, as three handfuls from another district. The clay soil yields the best.

Boulder Clay soil must be both drained and limed with freshly-burnt lime, while root-cropping is at a disadvantage—especially in a wet district—but oats, beans, wheat, clover, ryegrass, and timothy are exceedingly suitable. Ayrshire ryegrass-seed is much sought after by seedsmen, and the best is from the clay land; while in recent years timothy hay has become a speciality.

The "Great Chalky Boulder Clay" of East Anglia is another notable variety of this formation. Its material is believed to have been derived from the Oxford and other clays and the chalk deposits to the north-west of its district, and deposited at the bottom of a great extramorainic lake. Its characteristics, therefore, might be inferred as a marl with flints, and this is exactly what it

---

* Smith: "Great Ice Age in Garnock Valley," p. 189. *Trans. Geol. Soc. Glasgow*, 1890.

† *Trans. High. Agric. Soc. of Scotland*, 1879, p. 76.

is, being highly calcareous or chalky. The author has about 50 acres of it on his own farm, capping the undulations of the London Clay, and finds that it is the only arable land he has that is fit for cultivation, the rest being London Clay. These patches—one of which is not shown on the Geological "Drift" Map at all (No. 1, N.W.)—are among the most southerly of the glacial deposits in England. The formation extends to the north, and is the basis of the "Roothings" of Essex—one of the most famous wheat-growing districts; the "home of the steam plough" when it first became a practical success; and where a greater proportion of wheat was, and is, grown to the total area than anywhere else in the United Kingdom; while it is celebrated for malting barley as well. In the course of ages a large part of the lime has been dissolved out of the surface layer, but there is still sufficient left to supply the soil for plant needs; while the existence of marl-pits shows that much of this marly clay was dug and spread on the surface in the olden times; in fact, if the subsoil is dug into almost anywhere, beds and streaks of bluish-white marl are found in abundance. "It varies a good deal in composition, and though on the whole nearly impervious, is by no means so thoroughly impermeable as the London Clay."* It forms "a strong loam" only in comparison with the adjacent London Clay.†

The Great Chalky Boulder Clay covers about 3,000 square miles in the Eastern Counties, reaching into Lincoln and Yorkshire, in the latter of which it meets with the extensive deposit of the purple Boulder Clay brought from the north. It is held by Lewis to have been deposited in an extramorainic glacial lake, as there are no fossils in it, while it has all the appearance of a fresh-water deposit of glacial origin.‡

The general features of the country covered with Boulder Clay are rounded and undulating, especially looking down the valley or direction the ice has taken. It has tended to cover up all inequalities of the deep-seated rocks, going up over the tops even of the lesser elevations, and forming deep accumulations *behind* these—the "crag and tail" of geologists—and well up the hillsides in the valleys, and over the lower grounds in great sheets. It is

---

* Holmes: "Notes on Essex Drift Maps." *Trans. Essex Field Club*, 1886, p. 27.

† *R. A. S. E. Journal*, 1871, p. 281.

‡ Carvill Lewis: "Glacial Geology of Great Britain and Ireland," p. 58.

thickest in the valleys and lowlands, and thins away as it approaches the hills or rises up the valleys.

It has, of course, been greatly modified by subsequent erosions and deposits of more recent times, while many of the glens, and even valleys, in northern parts have been wholly formed by channels cut down through this to the older rocks below, leaving bluffs or terrace edges, now mostly covered by natural hardwood timbers, and distinct from the ordinary terraces of river formation. It is a soil that needs draining and liming to develop its cropping power, and it is on this that the Scottish nineteen-year leases of farms did so much in bygone generations to develop a race of improving and progressive farmers. The long lease made it worth the while of a tenant to develop his farm, as he was certain of reaping some benefit from his improvements before the expiry of his term; while the work of carrying out the improvements developed his farming skill. The draining, liming, clearing out the boulders to build houses and dykes or make roads therewith, the cultivation of a clay soil, the harvesting of crops in a wet climate, and the daily consumption of the best quality of oatmeal, either as porridge or "cakes," have developed a race of farmers acknowledged to be among the best—if not the very best—in the world, and who find farming a comparatively easy job anywhere else when they spread themselves into other regions.

Glacial Sands and Gravels.—These deposits—belonging to both the interglacial and the post-glacial periods—may be taken together, as their characteristics are identical. They occur all over the country as mounds, ridges, and beds of gravel, sand, and even loam or earthy material mixed with them in many places. Kames, eskers, moraines, and morainic material generally are simply particular formations of these deposits, as they all have a common origin due to the action of glaciers and the flow of water from the melting of the same. Ordinary river gravels and sands differ from these in that they are much smaller in extent, form level beds, the materials are more water-worn and less earthy, and the deposits follow the line of existing rivers to a very large extent; while the glacial deposits are larger in extent, irregular in form, and occur almost anywhere excepting on the higher ground. On the "Drift" Maps this formation is shown by a light pink colour, and on the six-inch "Solid" Maps by a series of dots as described above. It follows the lines of the valleys in a general way, and

sometimes forms wide stretches of land. Sand and gravel, of course, by themselves would form a very poor soil, but this particular group has generally a large admixture of earthy matter, and so, in a district where clay formations abound, or where the Boulder Clay is plentiful, it generally forms a good loamy soil. Several farms known to the author near Ongar, Essex—on the River Roden, and in the neighbourhood of Chelmsford, where the southernmost portions of the Chalky Boulder Clay tail off on the higher ground on the northern watershed of the Thames Valley—are on this formation, and the loamy gravel soils of these are among the best in the district, and compare favourably with the stiff clay soils of the Boulder Clay and the London Clay of the neighbourhood.

On the great central plain of Ireland the gravels of the "inter-glacial" period are largely distributed, constituting what is generally known as the "limestone gravel" because largely made up of pebbles of carboniferous limestone,* the drift there generally being strictly local in its origin.†

Where the gravels and sands are not earthy, there is, of course, a more or less barren soil, because any material of use to plants which might be deposited on the surface will not accumulate, but gets wasted away or washed down out of reach of the plant roots. Sand and gravel being necessarily of this nature, it follows that in some cases the soils on this formation are poor and hungry; in the cases where they are good it will be found to be on account of some local admixture with earthy or clayey material due to the readily ascertained action of surrounding circumstances.

Associated with these there are many patches and beds of what is described on the "Drift" Maps as "pebble gravel"—coloured deep pink—and generally capping the heights in south-east England. It is considered to be older than the Boulder Clay, as this has been seen to rest on it, but is very small in extent, forming only the cap of such hills as Highbeach and Gaynes Park in Epping Forest district, and Hadleigh, Rayleigh, and Langdon Hill in south-east Essex. Across the Thames, Shooter's Hill has the same kind of top. It is simply a barren gravel on those spots known to the author, given over to gravel-pits and the growth of birch or copsewood. In a clay country, however, such spots are

* Hull: "Physical Geology and Geography of Ireland," 2nd Ed., p. 111.
† Bell: *Geological Magazine*, Vol. X., p. 448.

valuable as a source of road metal where nothing else is to be had. The author has about an acre of it under cultivation, forming the corners of two arable fields, and has never seen a good crop grow on it yet, or any result from applying manures.

Other beds of gravel—coloured orange on the "Drift" Maps—may here also be mentioned. They occupy spots of no great size, and are of uncertain age, being either glacial or post-glacial.* These may be reckoned absolutely barren for farming purposes—Norton heath, near Chelmsford, being a good example, though there are other spots elsewhere.

Boulders and Erratics.—Scattered over great areas of the country, more especially in the district in the south of Scotland to which the general name of the "Southern Highlands" is given, there are an immense number of stones and boulders to be found, some on the surface or even out on the open as "perched blocks," and others embedded in the soil in countless numbers. These are a very distinctive feature of some parts, and interfere immensely with farming operations. It is unnecessary here to enter at length on a treatise as to how they came to be where they are; suffice it to say that they must have been deposited, either from glaciers, or more likely from icebergs floating in a shallow, quiet sea, when the land was only partially submerged. They consist of all sorts of rock, but mostly of granite, greenstone, schist, or some other of the older or harder rocks; and while some have been transported from a distance—such as the syenite of Ailsa Craig to North Wales, and Shap Fell granite into Cheshire—they, for the most part, have been brought from rocks *in situ* in the immediate neighbourhood. Agriculturally they are a great nuisance, for while out on moorland or upland ground devoted to sheep and cattle walks they may be let alone, yet whenever an attempt to cultivate a piece of land or lay off a proper square or straight-fenced field has been made, it was first necessary to clear off these stones and boulders—build as many as possible into the stone dykes, sleigh others off to fill up hollows or corners somewhere, and sink others deep enough to be below the ploughshare. The clearing of some districts has, indeed, occupied two generations of farmers, and is not finished yet, while the amount of money spent in thus clearing away this refuse of

* Holmes: "Notes on Essex Drift Maps." *Trans. Essex Field Club*, 1886, p. 28.

the Great Ice Age must be enormous. One farmer known to the author paid 4d. per stone to have the larger ones sunk below plough-level, as the easiest way of getting rid of the hundreds which encumbered his land; while a writer in the *North British Agriculturist* estimated that, in Galloway, this improvement cost as much per acre, and was as important as draining, and argued that it ought to have been included in the same schedule in the Agricultural Holdings Act.

"The greater part of the tilled land of New England, Canada, Northern Britain, and much of that of the northern parts of Europe has been won from these boulder-covered fields. The farmers heap the stone in great walls or upon the surface of the bare rocks; or where the erratics are too large to be readily moved they excavate a pit beside each one, and so provide it with a place of burial so deep that the plough will not touch its top. In New England, it is probable that more labour has been expended in this tedious task of clearing the boulders away from the tilled ground than has been given to the construction of all the roads and farm buildings of the country."*

The author has seen land in the act of being reclaimed from this wreckage of the Great Ice Age in Massachusetts, where the boulders and stones were bulkier than the brown loam among them, and their removal as big a job as the raising and carting or sleighing off of a continuous pavement. In some fields in Upper Nithsdale, well known to the writer, the boulders lie so thick on the surface or partly embedded in the earth, that a person could step from the one to the other right across the field. In this case the land was unreclaimable for this reason, though it is fairly good pasture for a cheese-making dairy herd of the hardy Ayrshire cow. In many cases the fields have had their load of stones completely gathered up and utilized by the work of generations of farmers and their men, and we see now nothing but square, trig, well-farmed fields, with nothing to show or prove how much money, time, sweat, and sore work has been expended in making those fields as they now are. It is an interesting and curious fact, however, that the ancient or prehistoric state of many farms as regards these boulders and erratics is preserved in the Celtic names of the same. A few of these, by way of example, will best illustrate this curious philological

* Shaler: "Origin and Nature of Soils." *United States Geol. Sur. Ann. Rep.*, June, 1891, p. 237.

and geological fact—names which are often re-duplicated all over the glaciated areas; such, for instance, as:—

Auchincloich, "the field of stones."
Garclaugh, "rough with boulders."
Clauchrie, "bouldery stream," and so on.

Wherever, indeed, throughout Scotland the Gaelic *clach* or *claugh* (a stone or boulder) forms part of a farm or place name, it is an indication that at one time, if not now, Boulders and Erratics were characteristic of that spot.

Moraines.—If, according to some geologists, there are not within the limits of the British Islands very many true moraines, there is at least a large amount of morainic matter. The reason for the possible non-existence of true moraines is two-fold: first, because of the slow and gradual decline of the glaciers not allowing any large, terminal moraines to be accumulated; and secondly, because of the destructive action to which all moraines have since been subjected in the course of ages. True moraines, however, are quite common in these Islands, though, of course, small compared to those abroad.

Their normal position is across a valley and partly up the sides thereof, generally at the mouth of the valley, with perhaps a succession of them one above the other. In most cases they have been cut through by the stream, but where this has not yet taken place the waters have been ponded back to form a lake, swamp, or a level stretch of alluvium or peat. One of the most typical instances of this occurs at the Inch Loch of Castle Kennedy, near Stranraer.

A typical moraine consists of angular and subangular stones, mixed with earthy matter or rock débris; the soil on the top is stony, covered by a scanty vegetation, while the material, of course, partakes of the nature of the rocks up the valley from whence it was derived.

In Ireland, many of the inland "loughs" owe their existence to being dammed up by moraines. Lough Bray, many of the loughs on the southern slopes of the Connemara Mountains, the picturesque little Glendalough at Recess, and so on, are all examples.*

* Hull: "Physical Geology and Geography of Ireland," 2nd Ed., p. 135.

Another good example is at the foot of Corsincon Hill, in Upper Nithsdale. A morainic accumulation of sand and gravel dammed up the valley, ponding back the waters of the Nith and Afton to form a loch some five miles long and two miles across at the widest, with the water getting exit at the upper end over into the basin of the Ayr. In the bottom of this shallow stretch of water the gravel, sand, silt, and even peat accumulated to form the meadows and holms; a stretch of level and in places still swampy land, on part of which the author served his apprenticeship at the ploughtail, and bore his share of the burden and heat of the day in the harvest field, in the days before the invention of the string-binder. The Nith succeeded in cutting through the morainic bank, and draining off the water; but it must have been in comparatively recent times, for the names of many of the farms prove that their sites were on the edge of a loch, or stretch of water, in the days when the native tribes spoke Gaelic, and before the advent of the *Saissonach* with his Scoto-Saxon speech. Thus, Polshiel means "the fish pool," Polquhirter "the herd's pool," and Polquheys "the muddy pool." There are no pools there now; but as these farmsteads stand at the edge of the alluvial tract, they bear evidence in their names of the times when the water was depositing the same—another curious illustration of how geological features or phenomena influence the names of farms, and examples of which can be found all over the country.

The morainic matter is not always in heaps or ridges, however, but sometimes spread out in level sheets to form fields. An example of this occurs along Watling Street to the west of Cannock, where the land is level, but covered with poor "drift sand and quartzose gravel," and much of it in larch and pine woods.

Although British moraines may be comparatively small and insignificant, yet they exercise a considerable influence on the nature of the farming where they occur. Bearing in mind that a moraine is normally deposited at the end or edge of the ice-sheet or glacier, we ought to look for the same running across England in a line or lines corresponding to the greatest extent of glaciation, as shown on the map, and also along the edge of the ice-fields in Wales and Ireland. This is exactly what we do find,* and many of these ridges of gravel and stones are conspicuous features of the landscape, and known locally by various names, and are sometimes

* Carvill Lewis: "Glacial Geology of Great Britain and Ireland," p. 22.

reckoned "hills" by the resident population. It is not necessary to follow this along its whole line, but one or two important examples may be mentioned. "The moraine in Holderness is a conspicuous feature of the landscape, and formerly enclosed a multitude of small meres; most of these are now artificially drained."* At Scarborough it completely choked up the Derwent, and caused it to find a new course, while it forms a great arc across the Vale of York—York City and Marston Moor being both situated on it. At Markington one of the mounds was thought to be a barrow by the local archæologists, who dug into it for treasure-trove in vain; while at Ilkley the Ordnance Survey has entered some mounds in the maps as "Roman forts." At Fountains Abbey the owner has covered the ridges and mounds with rhododendrons and other evergreens, thus forming a picturesque spot. Taking Yorkshire generally, it is found that northwards, or *inside* of these gravel mounds, the Till is deep, while southwards, or *outside*, there are aqueous deposits only, with a corresponding influence on the soils. The lateral moraine of the Ribblesdale glacier may be followed high up the mountain to near Skipton; while on Rumbles Moor, at an elevation of 1,175 feet, it is known by various names, such as "Laneshaw Delves," "Skirtful of Stones," "Long Ridging," &c. It can be traced down the side of the hills to the east of Burnley, Manchester, and Macclesfield, and so on across the country to the north side of the Wrekin, where it coalesces with the wreckage of the Welsh glaciers, running on to Carnarvon. The united moraines can be followed continuously from the Humber to the extremity of Carnarvon, a distance of 550 miles in length across Central England. "This line, which rises from sea-level to about 2,000 feet, cannot by any possibility be interpreted as a sea beach. From end to end it has the same typical contours, though composed of different rocks; whether it lies in a river valley, upon a plain, or upon a mountain slope, it has the same shape and features, and is identical with the moraines of modern glaciers in Switzerland. The great ice-sheet which it bounds is in reality an assemblage of confluent ice-lobes, and we have distinguished the more important of these glacier streams bounded by the moraine as respectively the North Sea glacier, the Irish Sea glacier, the Stainmoor glacier, the Wensleydale glacier, and the Aire glacier. In Wales the Arenig and Llanberis

* Carvill Lewis: "Glacial Geology of Great Britain and Ireland," p. 27.

PLATE VII.

Raised Beach: Turnberry, Girvan, N.B.

River Terraces: Newton, Clydesdale, N.B.

glaciers may be mentioned, but at least twenty others can be distinguished."

"Excepting where it separates the Welsh glaciers from the Irish Sea glacier, this great moraine everywhere marks the extreme limit of glaciation with solid ice in England, and is an important feature which might well be marked on the Geological Map of England."* (Map.)

In Wales, excepting in the extreme north, the glaciers were of strictly local origin, each confined to its own valley, there being no evidence of a great ice-sheet there.† Thus the surface deposits of all kinds are each there confined to its own district of origin, even the erratics (found up to 1,200 feet levels) being either grauwacke or slate.

While moraine formations are comparatively small and insignificant in the British Islands, if we go abroad we find them of enormous extent in some regions, and having great influence on the farming in many cases. Thus, the district known as the Dombes of Bresse, in France, is of morainic origin, and has a peculiar system of mixed farming and fish-pond management adapted to its circumstances.‡

Another example of still greater extent and importance is the "Grand Coteau" of Missouri. This is a great mass of glacial detritus and ice-travelled blocks resting upon a sloping surface of rocks of Cretaceous age, and extending diagonally across the central region of North America from south-east to north-west, a distance of about 800 miles. On the 49th parallel (the boundary line between Canada and the States) the Coteau is 30 miles wide, and it broadens out somewhat as it is traced northward. As the Coteau is ascended from its eastern base the surface is seen to become more undulating, and in its upper parts the drift materials are confusedly accumulated into low hills, which, however, seldom attain a greater height than 100 feet above the general level of the Coteau, the average elevation of which at the 49th parallel is 2,000 feet above sea-level. The Coteau belt is practically destitute of drainage

* Carvill Lewis: "Glacial Geology of Great Britain and Ireland," p. 40.

† Keeping: "Glacial Geology of Wales." *Geological Magazine*, June, 1882, p. 256.

‡ Risler: "Geologie Agricole," Tome III., p. 71. "La Dombes est une vaste moraine: elle se compose de débris de toutes sort de roches amenés des Alpes par les glaces; les blocs, de diverses grosseurs, anguleux ou émoussés, polis ou striés, sont dispersés au milieu de menus materiaux, le tout lié par une boue argileuse très abondante."

valleys, hence the waters of its lakes and pools are charged with salts, particularly magnesium and sodium sulphates. The western part of the Coteau contains wide, deep valleys with tributary *coulées*, mostly dry, or else occupied by chains of small lakes, which dry up in summer and thus leave large white patches of efflorescent salts, presenting a marked contrast to the crimson tufts of the marsh samphire (*Salicornia*) fringing the border. Besides the smaller sheets of water there are much larger saline lakes, such as the Old Wives' Lakes, which are persistent. The Missouri Coteau is about 400 miles west of Winnipeg, and fringes the eastern margin of the third and highest prairie steppe, which extends with a gentle ascent westward to the base of the Rocky Mountains.*

Geologists are pretty well agreed that this great physical feature of the prairie region is a huge moraine deposited by a glacial sheet, which, during the Great Ice Age, crept southward and westward from the higher rocky Laurentian and Archæan regions surrounding Hudson's Bay, and which left other isolated deposits—such as the Touchwood and Turtle Mounts in the middle prairie steppe. It is as large in extent as twenty average-sized English counties, reaching from North Dacotah right across Assiniboia, while the agricultural and physical features, as pointed out above, are in marked contrast to the level fertile prairie on both sides of it. Its stony, gravelly soil, its irregular, hillocky formation, and its alkaline waters mark it out as essentially "bad land," which will not be settled by a farming population till the good "sections" of the prairie—even those held for a rise by syndicates and railway companies—have all become occupied.

The Missouri Coteau, however, is only a part of a still larger moraine, or series of moraines, which have easily been traced right across the North American continent from Dacotah, through Wisconsin, Ohio, and all the other middle States, to the Atlantic at New York and Cape Cod. Where the ranges are all close together the breadth is 30 miles (as at the Canadian boundary) up to 50 miles; but where they are separate each may be from one to six miles wide.†

This moraine holds its course two-thirds of the way across the American Continent—for over 3,000 miles—while it is unknown

* Fream: *R. A. S. E. Journal*, 1885, p. 224.

† Chamberlain: "Terminal Moraine of the Second Glacial Epoch," p. 310. *United States Geol. Sur. Ann. Rep.*, 1882.

how far it reaches into the unexplored regions of the North-West Territories of Canada. It is probably the largest moraine in the world, though possibly the string of moraines which, beginning on the West Coast of Ireland, stretch right across the middle of Germany into Russia, may be quite as large.

While some geologists are still doubtful if there are any true moraines in the proper sense of the term within the British Islands —though a good deal of morainic material exists—it must be explained that some of the most eminent men hold that the Boulder Clay or Till, with its associated "drift" of sands and gravels, which overlies not only a large part of the valleys and low grounds of these Islands, but also many thousands of square miles of Northern Europe, is the remains of the *moraine profonde*, or ground moraine, of a huge series of glaciers—separate or confluent—and which overlaid the whole of Northern Europe in the Great Ice Age. As stated in the introductory chapter, the author believes the *moraine profonde* to be a myth, but, as the province of this book is to discuss matters from a farming point of view only, any further debate on this subject would be out of place.

Kames, or Eskers.—In the last stages of the Great Ice Age each elevated region of the northern parts of these Islands was a centre from which local glaciers flowed down each valley, as we see exemplified in the Alps on a somewhat larger scale at the present day. Each little glacier was, of course, accompanied by its load of boulders, stones, and other wreckage brought down from up the valley, and, in melting, discharged this at its lower end as a true moraine. The water draining away washed out and sorted over this débris, leaving the coarse material in the form of ridges, heaps, and hillocks of water-worn stones, gravel, and sand in various irregular positions at the lower end and sides of each upland valley. These ridges and mounds are known as *Kames* or *Eskers*, the rounded hillocks as *Drumlins*, and are here looked upon as modified moraines or morainic material, deposited or re-assorted by the water of the melting glacier, and which, though perhaps insignificant geologically, are important features in some places. Their distinctive characteristic is that they are composed of *water-worn* gravel or stones in contradistinction to the *angular boulders* of a moraine proper.

On many of the upland farms in northern districts these kames are a conspicuous feature, forming a ridge of barren, stony soil,

sometimes right across the middle of an otherwise fertile field. In the case of one known to the writer, on the farm of Bennan, in the Girvan Valley, near Straiton, Ayrshire—and occurring right in the middle of an alluvial flat—the thin, stony soil on the top is cultivated with the rest of the field (the plough going right up one side and down the other); yet the body of the same is formed of such clean washed stones that carts are backed right into it and the material is loaded up and taken away to make road metal. The soil, of course, is just gravel and sand, which no amount of manure would make fertile, and which would not be cultivated but because it is part of an otherwise good arable field. Some of the hillocks are conspicuous in upland districts on account of the short, smooth, green pasture on them, showing up against the surrounding heather and other coarse herbage of a moory hillside; the sheep soon find out they have a dry, sweet bite where the gravel below drains away naturally the excessive moisture of a district with a heavy rainfall, so that often these kames show themselves conspicuously as green hillocks and ridges—as at the head of Glen Afton, in Ayrshire—some, indeed, being known in many districts as "Greenhills" or "Fairy Knolls."

According to some of our authorities, kames have been formed by the action of water, as the sea heaps up ridges of sand or gravel at the mouths of rivers. They may be found at any height up to 800 feet above sea-level, and the most striking thing about them is their irregular and unaccountable distribution—sometimes on the top of a hill, sometimes in the valley. Some kames undoubtedly owe their existence to marine action alone, for there are many on the coast of Peru,* where there never could have been any glacial action. The Peruvian ones being in a rainless district, are still dry, bare ridges of stones, gravel, and sand, while the grassy covering on the British ones is due to the moisture of our climate.

Assuming that the central plain of Ireland was at one time a shallow sea surrounded by glaciated islands, we can understand that eskers will be plentiful thereon, and the Curragh of Kildare—formed of flat, undulating, gravelly hills—is a notable example of what Kinahan calls a *shoal* esker,† piled up by the eddying currents of a shallow sea.

---

* Holmes: "On Eskers or Kames." *Geological Magazine*, October, 1883, p. 6.

† Kinahan: "On the Eskers of the Central Plain of Ireland." *Trans. Geol. Soc. Dublin*, 1864.

The most common place to find them is at the point where the streams leave the narrow glens among the hills and emerge on to the lower ground, and are, therefore, for the most part looked on as the result of floods from the melting of small local glaciers during the final retreat of the ice.

Raised Beaches.—On some of our shores there exists a level strip of land about 20 to 25 feet above the level of the tide-datum, and reaching from the sea-edge to the foot of the higher land inland a little. This is geologically classed as a "raised beach"—*i.e.*, it represents a plane formed in bygone ages by the action of the waves when the land stood at a lower level than it does now, and the sea beat directly against the foot of the adjacent hills or higher land. One of the principal examples of this formation is along the south-west coast of Scotland, in Ayrshire and Galloway, but it exists in many places round our shores. It is seldom that any farmer is to be congratulated on the possession of fields on this formation. It has turned out a particularly good natural arrangement for allowing men to make good level roads round some parts of the coast, for supplying a level site for homesteads, and for towns and villages, of which Girvan and that "ancient borough" in a "sandy valley" celebrated as "Auld Ayr" are good examples; but the soil itself varies from blown sand to shingle, or even boulders, and it is only by the most skilful farming that the farmers of the "Carrick shore," for instance, can get good returns from the same. The Prestwick and Portland Sands, to the north of Ayr, are examples of the worthlessness, agriculturally, of blown sand—a formation to which a special colour is allowed on Geological Maps, though formed on a raised beach. It is with difficulty that such can be kept within control, and the covering of sand be kept from spreading. Most farms, indeed, with land on this formation have fields which dare not be ploughed up and cultivated, for fear the wind would sweep the whole top away. Examples of this sort occur on the farms of Kinning Park (the scene of a famous experiment in liquid manuring in bygone years*) and Greenan, both near Ayr, and Girvan Mains and Turnberry, near Girvan. (Plate VII.) Where it is a little earthy it makes a warm, friable soil, and in a dropping season enormous crops of early potatoes are raised where enough manure has been previously put into the soil, while Italian ryegrass for forage, or hay and carrot growing, has been

* *R. A. S. E. Journal,* 1858, p. 529.

carried out with the best results, as on Braehead Farm, near Ayr. On the poorer sands, again, lupines have been grown for sheep-feed with advantage.

The soil is a sieve itself, and would "eat a horse and its collar" in a twelvemonth if buried therein, according to local tradition. Until recently, it was a soil celebrated for growing rye, and rye-bread was one of the staple foods of the above locality, and as King Robert the Bruce was Earl of Carrick, and was "raised" at Turnberry Castle, it is just possible that he owed some of his mental and bodily strength to the rye scones of his youth—seeing that they would be tough enough for anything of this sort—and thus, indirectly, a few sandy fields on a fragment of raised beach on the coast of Ayrshire were the salvation of Scotland, and started Scotsmen on their mission of annexing England and inheriting the earth. Great things thus spring from small beginnings.

Sometimes, however, the sand gives place to shingly or stony land, according to the nature of the rock inland; while some of the earthy débris may have worked down from the higher ground in the course of ages and thus given it "body." The characteristic features are, however, that it is more or less level, that no clay is found in it (as the sea action washed out all likely to be present originally), that it is porous and loose in the bottom as the material varies from sand up to stones, requires no draining, and is a "hungry" soil because all manurial material wastes and washes downwards and out so readily, and therefore it is often left in natural grass.

Other examples occur at the Craigentinny sewage meadows, near Edinburgh, and the barren Sandwich Flats on the coast of Kent.

In some places there are traces of two or three raised beaches, one above the other, as at the Craigentinny meadows. From a farming point of view they are similar, and stand to one another in much the same relation as the upper and lower terraces of alluvial deposit.

In some parts, again, there are evidences of beaches formed by the action of lakes which have disappeared. These beaches show as gravelly and shingly level lines along the face of the hills or higher ground in some of our valleys—such as in Clydesdale—while the famous Parallel Roads of Glen Roy are another example. Such formations often come in handy as a site for farm roads and even public roads and railways, while the soil on the same is of the lighter class, with no clay present.

Estuarine Deposits. There is one particular form of alluvium which calls for special notice. This is that which is deposited in the estuary of every river, more or less, and which, when it becomes raised 20 to 30 feet above the level of high tide, forms a stretch of flat land of greater or lesser extent. The various "Carses" of the country are examples of it, and this deposit is believed to belong largely to the period of the wind-up of the Ice Age, when the valleys were occupied by small glaciers. These valleys being for the most part on the older formations yielded more clayey débris to the eroding action of the ice, along with a greater volume of water, and thus the bulk of these clayey flats were then laid down, anterior to the alluvium of recent times.

As a result of its origin, the clayey material is found to be largely composed of the "flour of the rocks"—that is, not clay from the decomposition of felspathic material, but the fine "flour" ground off the rock surface by glacial action.*

Following the rule about deposits down the length of a stream, we find that this is always composed of the finest of the materials which are found on the river course, and so it is either formed of clay—if any is brought down by the water at all—or sand in exceptional cases. Estuarine mud, indeed, is the technical name for the same before it rises above tide-mark and becomes consolidated into ground.

As bearing on the deposition of this mud, it is interesting to note the fact that the finer particles of clay will float perpetually in water and never become deposited by the action of gravity at all, this being more especially true of the "colloid" part; but that whenever it comes into contact with salt or alkaline bodies in solution in the water there is an immediate precipitation of the fine floating clay. In this way the "bars" at river mouths are deposited, and these form the estuarine flats when the accumulations rise above tide-level. Thus the land of an estuarine deposit is typically clay, and devoted to the cultivation of "strong" land crops such as wheat, beans, and hay, with bare fallows to clean the land, as on the level lands of the Forth and Tay; while the nature of the clay varies according to the nature of the prevailing rocks up the river course—more particularly in colour.

Some noted farming districts in the country situated on this formation may be given by way of example:—thus the Carse of Gowrie, the Carse of Stirling, the Haughs of Clyde, the Fens

* Geikie (J.): "Prehistoric Europe," p. 398.

(below the peat), Romney Marsh, and various other places are typical, yielding the characteristic soils of the same, and notable for the farming thereof.

It is interesting to note that the Norse name "carse" (a meadow) is applied to this kind of formation and its soil all round the country, as if our Norse forefathers had noticed the peculiarities and similarities of the same on different rivers. An example may be given on the Galloway shore of the Solway Firth. The river Cree brings down a large body of fine, bluish, clayey material from the Silurian uplands, varied with some yellow, clayey deposits from the granite boss of Cairnsmuir-of-Fleet, and these form the basis of a number of farms with "carse" as part of their names. Thus we find—beginning on the west side of the estuary—the following:—Carslae, Carsegown, Carse of Clary, Carse of Bar, Carsnaw, Carse Duncan, Carseminnoch, Carsewalloch. Again, further west in Dumfriesshire there is the Carse of Æ, as, indeed, there are many more over the country besides the well-known ones of Gowrie and Stirling. (Plate III.)

While estuarine mud is in the transition stage, before it becomes consolidated into land above tide-mark, it forms *salt marshes* and *samphire ground.* These are generally valuable for grazing purposes, the excess of saline matter making such land healthy for live-stock where the surface is not too soft or too much cut up by tide runnels.

There is one particular form of estuarine deposit which gives rise to a variety of farming on some of the estuaries of the Irish coast—such as in Belfast Lough. This is called "slob-land," the "slob" being simply the shore mud which has been taken in by a sea dyke, and the high tides kept out—pumping having to be sometimes resorted to. A slob-land farm is thus the counterpart of a Dutch polder, and is often of great fertility.

One point connected with the fertility of the various varieties of soils of this group is the fact that the fresh water brought down teems with microscopic life—animal and vegetable. The first touch of salt water kills these organisms, while those in the sea-water are also killed from meeting with the fresh water, so that there is a constant deposit of this rich organic matter, along with the clayey mineral matter, and thus estuarine flats are fertile, as we see at the mouths of rivers like the Humber, Wash, Thames, and Bristol Channel, all our carses, and the polders of the Rhine and Meuse.*

* Gaye: "World's Great Farm," p. 44.

Terraces.—Accompanying the alluvial flats of our streams there are often "terraces" to be found, from one to four in number, along the edge of the higher land bounding the valleys. These are the remnants of an older stratum of alluvium deposited at a higher level at a time when a greater volume of water ran in the stream and the valley had not been scooped out to so great a depth, or the water was temporarily dammed up to a greater height. Being simply the remains of old alluvia, they are similar to the newer of the same place, and follow the same rule of being clayey nearest the hilly ground and gravelly nearest the side where the stream formerly ran, if the part left is extensive enough to show these variations. They generally occur in the lower reaches of a valley, the upper parts being free of them, while they do not occur in every valley. Clydesdale has some of the most typical examples of terraces, partly of a clayey and partly of a sandy nature. It is not always easy to recognise them, because the weathering agents acting on them for ages have in places so obliterated and sloped off the edges or bluffs that they can be cultivated, and two levels sometimes form part of one field. In many other cases, however, the divisions between are marked by a steep bank or bluff—planted with trees where the managers of the land know their business—and sharply outlined, as represented in the diagram on p. 121.

Newton Farm, near Cambuslang, is a typical example of this formation, showing three different terrace levels, with the wooded bluffs between in some parts, and the soil ranging from gravel near the River Clyde, through sand and loam, to clay at the side furthest from the present bed of the river. The greater part of the farm is on the 100-feet terrace, and consists of a light, workable loam. (Plate VII.)

Brick-Earth.—Up and down some of our southern river valleys there occur deposits of material which is variously termed brick-earth, brick-loam, or loess, and which varies slightly in its composition in different valleys. Each deposit of clay can be put into one or other of three classes: pure clay, marls, and loams—if looked at from a brick-maker's point of view. The loess form, which contains a considerable portion of calcareous matter, is peculiar to the Rhine valley and other valleys of the Continent, and is also found in China (forming the valley of the Hoang-ho), and also on the Mississippi. As its name implies, the soil on the surface is of an earthy nature, while it only occurs in circumscribed

portions in the valleys of southern streams, particularly of the Thames and its tributaries.

It is considered by some to be a fluvio-glacial deposit,* by others a wind-blown soil†; but, looking at its position and occurrence in small spots in the south of England, it will suit our purpose best to look on it as a variety of alluvial deposit.

It is found on the parts nearest the high ground, and its occurrence can often be detected afar off by the presence thereon of brick and tile works. The top soil is one of the finest in existence, being a perfect "loam"—in the correct sense of the term—in its physical characteristics, and of great fertility. There are some comparatively wide stretches of this formation in the neighbourhood of Southend and Rochford, and along the north side of the Thames Estuary. It is the highest rented land of that neighbourhood, and any farmer who happens to have a field or a patch of this soil knows its value, and makes the most of the same.

Temple Farm, at Prittlewell, near Southend-on-Sea, is a typical example of this soil, being of remarkably good chemical and physical composition, fit for all kinds of crops. Some patches also known to the author on the River Roden, in the same county, are prized by the farmers who hold them as spots on which they can grow mangels or other roots continuously—islands of fertile loam in a sea of clay or other inferior stuff. The contour is, of course, level or very slightly undulating, and is generally all in cultivation, for, although it yields large crops of grass, it is more valuable in cultivation in a county where the greater part of the land is too stiff for satisfactory arable cropping.

It is necessary to mention that some authorities affirm that there is no loess in Britain at all, but the agricultural characteristics and value of the soil of this "brick-earth" deposit mark it out at least as a special formation; while its position in the Thames Valley, and the fact that this river was once a tributary of the Rhine, seem to explain its occurrence.

---

* Geikie (J.): "Geology," p. 379.

† Shaler: "Origin and Nature of Soils," p. 328. *United States Geol. Sur. Ann. Rep.*, June, 1891.

CHAPTER X.

FORMATIONS AND FARMING.—V.

CONTEMPORARY OR RECENT.

Alluvium.—Wherever, along the course of a river or brook, we have a level stretch of land, we find an alluvial formation. It is, in reality, the silt brought down by the water, mostly in flood-time, and which has been deposited when the current died out and where the water had room to spread.

The original valley as left by the ice on the retreat of the glaciers would be comparatively deep and round bottomed; while, in the course of ages, the floods deposited their loads of gravel, sand, and clay, gradually filling up the same with a level sheet of material, the surface of which now forms our meadows and fields in valley bottoms.

In the northern parts of the North American Continent, and perhaps even in some of our own northern districts, the formation has been helped in places by beavers making their dams across a stream and thus aiding the deposition of silt. I have seen this very distinctly shown on the meadows on the farms of friends in Vermont, U.S.A., where the old dams showed as embankments across the level stretches, succeeding one another at various heights, and when dug into found to consist of logs and sticks buried in the silt.

On account of the fact that the land is so level, and often under the flood-mark, the soil is more or less wet and boggy in its natural state, and liable to be covered with flood-water whenever a period of wet weather sets in, and therefore we find often that there is little arable cultivation, although the physical texture and the natural fertility of the soil is eminently suitable for arable work. The reason of this is, of course, that the dampness is conducive to the growth of a large bulk of grass or other crop, which—although it may be more or less of a soft, overgrown nature—has the advantage of yielding a bulky return. On the other hand, an

arable crop such as corn or roots would be injured by overflowing water, in addition to the harm done to the growing plants by a waterlogged bottom.

The composition of an alluvial soil varies very considerably according to the nature of the grounds further up the stream from whence the material has been derived, and also according to the position of the spot in the valley longitudinally or transversely; but this variation is always according to certain natural laws, as partly explained in a previous chapter.

A river in its upper reaches runs with greater force because it is going through a more hilly district where there is a steeper fall than on the lower and more level land nearer the sea. The result is, that in a typical string of alluvial flats down a valley the upper ones will be gravelly or even stony, the middle ones sandy or silty, and the lower, where they merge into the estuary, of a clayey nature. Further, in going across a valley it will be found, in a typical case, that gravel predominates next the stream, then a sandy or silty tract, while a stiff clay often occurs at the foot of the higher ground furthest away from the river; all of which is due to the fact that the current is strongest at the river-bed in flood times, and dies out to perfectly still water against the rising ground. This is the reason why beds of clay are often found at the foot of a bluff, or where the rising ground bounds the edge of the alluvial tract, and it often puzzles the farmer to account for the existence of a stiff patch of soil adjacent to friable land, and in a district where clay is scarce. The alluvial soils of Clydesdale are a typical example of this arrangement of the materials up and down the valley as well as across the same, but it is the rule in all valleys, and any departure from the rule is due to some patent cause or agency easily explainable.

But, of course, besides this general rule applicable to all rivers, there is a difference in the general character of the alluvia of different rivers, due to the differing nature of the formations forming the drainage area of each stream. Where, for instance, Red Sandstone rocks prevail, we expect a red sandy alluvium with a reddish clay further down the stream or further off from the bed of the river, as exemplified in the valley of the Mersey; again, where the Keuper marl predominates, the alluvium will be of a red, marly nature, as in the case of the highly-rented meadows near Keynsham above-mentioned; while, on the other hand, if the rocks are of the nature of Silurian schists, then the alluvium will be formed of

bluish clay, as exemplified on the Forth and the Tay, and yielding stiff clay soil, rich in potash, and noted for corn and beans.

Some of the most extensive deposits of alluvial soils may be mentioned, but it must, of course, be pointed out that carses, warp-land, fens, bogs, and so on, are, to a certain extent, only varieties of this formation, and that it is often difficult to draw the line of demarcation between them. The carses of Gowrie and Stirling, the vale of York, the flats of the Ouse and Trent, the Fens (which are partly peat and partly silt), Romney Marsh, the Bridgewater levels of Somerset, from the Bristol Channel to Sedgemoor, furnish some of the richest grazing land in the three kingdoms*; and in Ireland the same may be said of the iand to the south of Lough Neagh.

In the neighbourhood of the Metropolis, the greater part of the alluvial soils are occupied with market gardens, owing to the greater suitability for this purpose as compared with the higher-lying, but stiffer and poorer soils of the adjacent formations.

As with many other formations, however, it is when we go abroad that we find the largest development of this. The Indo-Gangetic Plain of Hindustan—forming quite the half of British India—is wholly of this formation, laid down by the snow-fed rivers of the Himalayan range. In its upper reaches in the Punjaub and Rajputana there are large deserts owing to the want of rain, while nearer the sea, in the lower ranges of the Ganges, in the rainy regions the vegetation is excessive. The "primitive soil" is the same in both, however.† It is this soil in the Upper Provinces which responds to irrigation, and on which much government and private money has been spent. The deposit is sandy in the Punjaub and Rajputana, loamy in the North-West Provinces, and clay or mud in Bengal,‡ thus following the same rule of deposit as all other rivers.

The Nile Valley is another example of a great alluvial deposit. Egypt and the Soudan are barren wastes of rock and sand, and it is only the long, narrow, green strip of the Nile Valley which makes it valuable as a region fit for men to occupy and grow crops upon. The silty water brought down—as is well known—is pumped up on to higher levels than the floods naturally reach,

---

* Woodward: "Geology of England and Wales," p. 330.
† Buck: "Statistical Atlas of India," p. 10.
‡ Ibid., p. 16.

so as to make extra alluvial flats, while the great dam lately constructed will still further extend the effects by irrigation. The Nile silt is deposited along the flat shore land of the Mediterranean, as far as Gaza, in Palestine.

It will thus be seen that while one colour on the maps of the Geological Survey represents all alluvial deposits, and even sometimes includes peat mosses, the nature of any particular deposit must be studied in the light of the nature of the formations of the drainage area up the stream. The general facts are that such lands are level, subject to floods, but yield a big crop of grass and herbage; while the soil is the best of the neighbourhood because it is formed of a mixture of the débris of many formations. It has even been noticed that the alluvium from rocks which are by nature unproductive often forms a fairly fertile soil, and if it can be drained and embanked, or is beyond the flood-mark of the present time, it yields good, all-round arable land. Corn of all kinds grown on peaty Alluvium is generally brown in colour both as regards grain and straw, the dark colour of the soil affecting the plants grown on the same.

In its natural unimproved state, the land is often wet and marshy, requiring draining, and with a growth of inferior grasses, such as *Holcus lanatus*, *Glyceria fluitans*, *Alopecurus geniculatus*, *Carices*, rushes, &c., with the alder and willow for timber. Draining and liming will alter the characters of all these—even of land occasionally under water—the lime, or even slag, sometimes causing the white clover to develop from its previously dormant condition.

Warp.—The mud or silt brought down by some rivers even when there is no special flood is considerable, and advantage is sometimes taken of the same to cause it to be deposited over the adjacent land to form what is, indeed, an artificial alluvium. The Nile mud is an example of this on a gigantic scale, but it is carried out on some of our own rivers—especially in the Humber and Wash districts—pretty extensively. Where the tide meets the fresh water coming down—when it is high tide—the water is dammed back, so that while confined inside banks it rises higher than the land, and advantage is taken to lead it by channels on to the field it is required to cover with silt, and this is repeated until a sufficient thickness is deposited. This use of the tide can, of course, only be made in the estuary of the river; but further up the water can be led off by properly constructed channels to

perform practically the same work. The soil formed from this is in no wise distinguishable from the natural clayey alluvium or estuarine deposits of the river—being simply an artificial controlling of the deposition of the same—but it is likely that the particles of silt are finer, because in the natural flow of the water there would be greater speed, and consequently more sand, and even gravel, in the suspended material; whereas, in the artificial watercourses designed to lead off the muddy water the speed can be regulated, and only the finest particles including vegetable matter carried along and finally deposited when the water comes to rest on the enclosed field it is desired to cover over. The soil will thus be of the finest sediment, but otherwise the farming and cropping and other characteristics will be pretty much the same as with ordinary alluvium. As there is a special sign on the Geological Maps, however, for this formation, and as "warp-land" farming has some specialities of its own, it is necessary to point out some of the peculiarities of the same.

Potatoes are one of the principal crops of these districts, and those from the warp land of the Fens are particularly sought after for seed purposes in the south of England -as are also "Fen oats" —the commingling with peat no doubt helping the healthy development of the same. "Blackland" (Fen) potatoes, however, are poor for eating, and fetch the lowest price in the London markets. A peculiarity of "Fen oats" is the enormous length of the grains and chaff, a characteristic which disappears, however, when sown on other soils.

Warp land is, of course, exceedingly level, in common with Fen land, and the prospect is rather dreary when looking across an extensive area of the same. The farmhouses stand out by themselves, with only a few poplars here and there to break the monotony, and with the fields separated by banks and stagnant ditches suggestive of fever and ague.

It is principally on the lower portions of the Trent and Ouse, and the tributaries of the latter, that warping is carried out, as the water of these two rivers contains a large proportion of a yellowish kind of mud. This mud—the "warp" proper—is believed to be derived from the waste of the Till or Boulder Clay of the Holderness coast, "churned" up by the constant backward and forward motion of the tides, while the ordinary silt carried down by the rivers is mixed with the same. By means of suitably-arranged canals this muddy water at high tide is carried in some places as

much as seven miles, and distributed over large areas prepared for this flooding. The largest of the canals are 100 feet wide, on which ships of 100 tons burthen can pass, bringing in manure and taking out produce. It is chiefly peat and other inferior land that has thus been reclaimed by depositing from one to three feet deep of "warp" on it. In the process of deposition the same law is found to act as in the case of ordinary natural alluvium—that the heaviest particles are deposited first, nearest the inlet of the water, and the lightest carried furthest—and, therefore, the canals and banks have to be arranged so as to ensure a more uniform quality of the soil laid down. The soil is of a clayey nature, as are estuarine deposits for the most part, and, like ordinary alluvium, it is fertile for all crops both as to quantity and quality, but the grain crops are remarkable for the dark colour of the same, as is the case with those grown on alluvium and peat, though the colour brightens when the seed from the same is sown on other soil. This brownness is so marked a peculiarity that the seed-growers at Goole have to explain it to those customers who do not know of the same, and who would be apt to lay the blame on bad harvesting, or heating in the stack.

Peat Mosses.—Of the formation of peat* it is not the province of this book to treat; suffice it to say that it is formed of an accumulation of vegetable fibre, the remains of plants which have grown in a lake, swamp, or quagmire—*i.e.*, where there has been stagnant water more or less free from silting. Sometimes we find it on a hilltop or hillside, in a position where there could not possibly have been a ponding-up of water; but in such cases there may have been some damming up in bygone ages, of which no trace is left, or at least a spongy, damp spot, sufficiently wet to grow the *sphagneæ*, *hypneæ*, &c., which compose the peat. In other cases, patches of peat occur on alluvial flats with no distinct line of demarcation between it and the regular alluvium, while in digging or ploughing it is found that strata of peat and silt sometimes alternate. In Ireland these are recognised as two varieties: the upland *Black Peat Bogs*, and the low-lying *Red Bogs*.† In the Fens, the peaty matter is largely made up of the remains of *Hypnum fluitans*, *Claudium mariscus*, and various rushes, sedges, &c.‡

---

* From the Celtic *peait*, soft or miry.

† Kinahan: "The Waste Lands of Ireland," p. 1.

‡ Marr: "Scientific Study of Scenery," p. 240.

PLATE VIII.

PEAT (MOSS HAGG): AYRSMOSS, N.B.

SAND DUNES: TROON, N.B.

The depth of peat varies immensely—sometimes only a thin deposit, in other places many feet deep. When the bottom is reached in the thicker, low-lying tracts a bed of marl is generally found. This has been formed from the shells of the countless molluscs which have lived in the water before the growing up with vegetation, and which have partly mixed with the clay or silt of the bottom.

A peat moss in its natural state is soft and spongy, full of yielding, oozy spots and " moss-haggs," and covered with heather, cotton grass (*Eriophorum vaginatum*), meelic grass (*Molinia cærulea*) birch bushes, and other rough vegetation. (Plate VIII.)

The meelic or molinia grass has been recommended as a beginner in the reclamation of a bog, as it is natural to this soil, and has been found capable of great improvement both in quantity and quality by cultivation ; but timothy grass (*Phleum pratense*) grows well after the bog has been reclaimed and cropped.*

The soil formed from peat when reclaimed is a brown to black "fluffy" loam, very soft and spongy, and much improved by dressings of clay or any earthy material, or even by burning a layer of the surface. It must be drained to remove the superfluous moisture, and the pipes must be put down into the solid clay bottom to make a permanent job, or else the channels must be cut in the peat itself on the "shoulder-drain" system, as no drain-pipes will keep their places in the substance of the same without becoming displaced and working upward to the surface from the shrinking of the moss on the removal of the water. Where the peaty formation is of any extent, and more or less level, the drainage has to be done by large open ditches dividing the land into small rectangular fields of about eight acres each—as on the Fens, Carrington and Chat Mosses, and similar places—with the covered drains delivering into the same. In common with humous alluvium, the soil must be dressed with lime to act on the superfluous humus present, and where the afore-mentioned marl is near the surface it sometimes pays to dig it up and spread it over. Where the bed of peat has been cut away bodily for fuel, the bottom, when ploughed up deeply so as to mix the refuse with this marly layer, makes a fairly rich soil; but, as is the case with alluvial soil generally, the corn crops grown on the same are flaggy and weak-strawed, apt to become lodged, and ripening later than those on "harder" ground, while with turnips or other roots there is a

* Kinahan : "The Waste Lands of Ireland," p. 89.

tendency to grow much leaf with "fozy" bulbs—*i.e.*, soft, hollow, and easily rotted. Oats, and indeed all grain, tend to become brown in colour when grown on humous alluvium or peat, and thus the "pale" samples desired by buyers cannot be produced on such land, although otherwise the quantity and quality may be up to the mark. It seems as if the excess of humus present tended to dye both the straw and grain of the crops. Potatoes, however, are exceptional, and are pre-eminently suited to a peaty soil, and one reason undoubtedly why "praties" have become the staff of life in Ireland is the superabundance of bogs there, and the life-long training having made the labourers expert spadesmen in planting and raising potatoes on the "lazybed" system of husbandry—a system which trenches the land, drains it, cultivates it, and grows a good *fallow* crop all at one operation.

While it may be profitable to cultivate the bottom of a bog which has all been cut away, it would never do to cut the peat out for the sake of the land below. In some cases adjacent to rivers the owners have dug the peat out in masses and floated it away, but the result has been loss, and therefore failure.

Peat is found most largely developed in the northern and western parts of the kingdom, and in hilly districts, though some great level expanses of the same occur, such as the Bog of Allen in Ireland (77,500 acres) and Lough Gara (83,680 acres).* The conditions necessary for its formation are a cool climate and a heavy rainfall—a state of affairs mostly met with in the north and west of our Islands.

Shingle.—Along many miles of our coasts there extend beds of rounded pebbles or stones, forming the wave-washed portion of the shore, and to which on the one-inch Geological Maps a special "stippling" mark is assigned.

This particular formation is, of course, of no special value—as a substratum of a soil, or in any particular agricultural sense—but it certainly is of great importance to a farmer who contemplates taking a shore farm to know the particular nature of his shore, and if there is any extent of shingle thereon. As previously defined, the term *shingle* refers to large, water-worn stones, in contradistinction to the smaller ones known as *gravel*. It is, perhaps, necessary to explain again that some geologists have gone

* Kinahan: "The Waste Lands of Ireland," p. 120.

out of their way to apply the term "gravel" to angular, unwashed stones, a material which very seldom exists in nature at all.

From an economic point of view the material forming the shore of a farm may be of importance to the farmer thereon as a source of stones for road-mending, building, or similar purposes, and an idea may be gained of the value of this material to some people, when it is pointed out that some of our railway companies —the Great Eastern, for instance—engage to supply shingle, gravel, or sand from the shore, at 5s. to 6s. per ton, carriage paid, in waggon loads. Proprietors are generally alive to the value of this product of the foreshore where it exists (and it exists on every shore except those of a clayey formation), and jealously guard the "lifting" of the same; while the value to the farmer of an inexhaustible supply of road-making and mending material is not to be overlooked.

This sometimes occurs in places, however, as the foundation of fields or land of a sort, when forming part of a raised beach. One of the best examples of this is the bank of shingle running from Ebsfleet to Sandwich on the flats bordering the bay, where the Romans, the Saxons, and St. Augustine all landed at different times; and it is quite likely that these invaders all first stepped on shore on to this very bank. It is high and dry now, and forms a long ridge with a scanty covering of "bents," marram, and bird's-foot trefoils, and which burns up brown in summer, while the adjacent alluvial or estuarine tracts keep green.

Blown Sand.—Round our shores at various heights above high-water mark, there are in many places extensive accumulations of sand, variously known as Blown Sand, Drifted Sand, or Æolian Drift, and forming "dunes," "denes," "towans," "links," "rabbit warrens," &c., while parts may actually be cultivated, or at least grazed with stock. These sandy accumulations generally form part of a raised beach—nearly always the 25-feet one—but as they are assigned a separate colour on the Survey Maps, and are of importance geologically, lithologically, and agriculturally, it is necessary here to point out their position. That they are of extensive acreage is proved by the fact that Kinahan estimates that there are over 40,000 acres round the coast of Ireland alone,* about half of which he believes could be converted into arable land,

* Kinahan: "The Waste Lands of Ireland," p. 43.

and the rest improved by planting with the sea pine (*Pinus maritima*) for forests, or with mat grass (*Ammophila arundinacea*) for pasture, and to bind the sand.

The great difficulty with this sand is to prevent it from drifting. It generally exists in a series of dunes or ridges parallel to the shore, and sometimes rising as high as 250 feet, and these are in constant motion inland. The case is greatly aggravated in a storm—as exemplified in the historic case of the Culbin Sands, in Morayshire, where the destruction of the binding grass, followed by a storm, in one night overwhelmed a whole countryside, and converted a thriving farm district into a sandy desert. But it is always in motion, even in ordinary weather, where there is nothing to check it. The particles of sand work up the slope of the dune—as the prevailing wind is generally from the sea—and drop down the inner slope, so that in this way the ridges move forward a few feet every year. Farmers who adjoin or occupy such land have had to take special means to prevent this encroachment. Where there is a good coat of grass on it already it is pretty safe, and this is never ploughed up, while means are taken to extend and strengthen the same.

The seaward face of sand dunes is generally steep, but in no case does the slope exceed 30 degrees in fairly dry and loose sand, although it may look steeper than this.

Where the surface is fairly uniform, a coating of earth, clay, peat, road scrapings, or any earthy material does immense good, not only from its manurial value, but also from the mechanical adhesive effect of the same preventing the sand from being caught by the wind, and thus helping to form a good sound turf.

Where there is naturally enough earthy matter among the sand —as along the more inland portions—it may be arable, though the soil, being of a light, sandy nature, and very porous beneath, is liable to have its crops burnt up in a dry season. For this reason, in some districts in this country, and very extensively on the Continent, the lupine has been adopted as a reclaiming crop: its deep roots give it a hold on dry land of this nature, while it supplies forage for sheep-folding, thus manuring and consolidating the soil, the residue being ploughed in as green manure.

Outside the limit of cultivation, where the dunes must remain in their original condition, the native cover is usually marram, or mat grass—from the Shetlands to the Channel Islands—and as a binding material nothing can beat this, and its growth should be encouraged. Besides the sea pine for planting, the Scots pine (*Pinus*

sylvestris) succeeds very well in some places—as, for instance, on the Portland Sands (Ayrshire). There are, however, many sand-loving plants—such as the bird's-foot trefoils (*Lotus corniculatus, major* and *minor*), rest-harrow (*Ononis arvensis*), sand wheat-grass (*Triticum junceum*), red fescue (*Festuca rubra*), sand carex (*Carex arenaria*), lady's bedstraw (*Galium verum*), and gorse (*Ulex Europeæus*)—which materially help in binding the sand or in giving a food value to the pasturage. On the sandhills of Torrs Warren (Wigtownshire) the little silky willow (*Salix fusca*), the common heath (*Erica cinerea*), the cross-leaved heath (*Erica tetralix*), the ling (*Calluna vulgaris*), and even sheep's fescue (*Festuca ovina*) are common, and yield a certain amount of herbage.* On the Northumberland "links" the bright red geranium (*G. sanguineum*) is plentiful.† Indeed, the scanty grass and herbs have a special dairy value, for the milk from cows grazing on them readily throws up all its cream, while the churnability of this cream is also high in degree, and a large percentage of the butter-fat in the milk is thus recovered in the churning. Modern experience and research has shown that while the chemical composition of each cow's milk remains pretty nearly constant with all kinds of foods, yet the percentage of cream which rises on the milk and the percentage of butter which can be recovered from that cream vary very much according to the nature of the food. The wife of a shore farmer, whose cows are usually grazed inside the fences and on reclaimed ground where "improved" pasturage has been laid down, can always tell from her cream-crocks when the cows have been turned out on to the natural unenclosed beach where the sand dunes and shingle predominate, from the sudden increase of cream and butter which she has. This is not probably all due to any special herbage growing on the sand, as possibly the excess of salt and a nip of seaweed may be factors in the same‡; but the point is that on this particular geological formation, where it is in its natural state, the circumstances above stated occur.

The most profitable use to which such sands are put, however—where they are tolerably even and level—in the neighbourhood of

---

* Smith: "The Sandhills of Torrs Warren," p. 296. *Trans. Geol. Soc. Glasgow*, 1891.

† Topley: "Sand Dunes and Blowing Sand." *Pop. Sc. Rev.*, 1874, p. 135.

‡ Shetland sheep regularly eat seaweed.

large towns, is for sewage farm purposes, a soil of this kind on the shore making an ideal place for such, because it can drink up an unlimited quantity of liquid, retaining the solid, so that in a year or two it becomes an organic soil through which the water filters. The filtration is not perfect, of course, but that is of little account, because the filtered water makes its way directly into the sea without polluting any streams, while the sandy formation becomes a valuable soil for the growth of ryegrass, timothy, and other crops. Perhaps the most notable example of this use of the formation in question is in a small part of the Craigentinny Meadows, on the raised beach between Edinburgh and Portobello, where what in former years has been an expanse of loose sand is now one of the most highly-rented and heavily-cropping spots in the United Kingdom, from the sewage of Edinburgh being run over the same. The proposition to carry the sewage of Glasgow to the Portland Sands, on the Ayrshire coast, if carried out, would be another example of the agricultural utilization of a "Blown Sand" in the best manner, because the water thus led on tends by wetting to keep the sand from shifting, and to supply a crop with the moisture usually lacking on this formation, while the solid material supplies fertility and adhesiveness at the same time. (Plate VIII.)

Some of the other principal examples of this formation may just be named, as, for instance, the dunes on Sandwich Flats, Phillack Towans (Cornwall), Southport Sands (Lancashire), Torrs Warren (Wigtownshire), Turnberry Warren (Ayrshire), Lough Foyle (Londonderry), Murragh Foreshore (Donegal), and so on.

In some cases the sand is mixed with so much broken shell refuse as to be valuable for manurial purposes. The Cornish farmers considered it worth carting if it contained from 40 to 70 per cent. of carbonate of lime; and in 1836 De la Beche estimated that 400,000 tons per annum were carted into the country, about one-fourth of it from Padstow Harbour alone.

Whilst the sand-dune formation is limited in the British Islands, it is pretty extensive abroad on the Continent. Perhaps the best known is "Les Landes," on the Bay of Biscay, reaching from the mouth of the Gironde to that of the Adour, a distance of nearly 150 miles, with a maximum breadth of six miles; the heights rising to 300 feet. These were a shifting waste until planted with the sea pine (*Pinus maritima*) about the beginning of the nineteenth century. Before this they had covered fields and

villages, but the planting fixed them, and made the district industrially valuable. All along the shores of the North Sea from Dover northwards the coast is bordered by sand dunes, extending in some places six miles from the coast; while in Denmark, Schleswig, and Holstein there are about 240 square miles along the coasts. The industry of the peasantry has reclaimed some of these; in Holland, for instance, the growth of evergreens and bulbs being a great feature in the Haarlem district on a soil of this nature.

In Africa, if the Sahara is a dried-up sea bottom, then its sands would come into this class, as would the sandy deserts of the "East" generally. In Palestine, for instance, the coast from Carmel southwards is a raised beach with low hillocks of semi-consolidated sand; and the fertility of the Plains of Sharon and of Philistia (the Shepelah) is due to the admixture of this with the denuded materials from the chalk and limestone of the inland mountains.*

---

* Hudleston: "On the Geology of Palestine." *Proceedings: Geol. Assoc.*, Vol. VIII., No. 1., p. 13.

CHAPTER XI.

THE EVOLUTION OF LIVE STOCK.—I.

It must have struck many people who have no pretensions to scientific knowledge, and have only vague notions regarding the meaning of "evolution," that there is a vast amount of similarity between not only varieties of the same animal—as in the case of the horse, for example—but also between all the kinds of domestic animals. If, however, they have some knowledge of anatomy and physiology, they will be aware that there is also a great deal of internal similarity among the parts and organs of the different kinds which is not apparent to the casual observer, besides the outward points of resemblance. Further, if they extend their inquiry to the case of many animals which are not domesticated in these Islands, though domesticated abroad, and to many others which are wild—such as reindeer, llamas, camels; deer, bisons, tapirs, and so on—they would find an equal amount of similarity among them. This agreement in form and functions of the whole or the parts of individuals of one species with the individuals of another species is—to put it shortly—due to their having a common ancestry, that is, to all these species or breeds or varieties being descended from one primeval ancestor.

Approaching the subject from this point of view—that of ancestry or parentage—we open up a most interesting field of research. It used in olden times to be a half humorous subject of discussion, whether the hen or the egg came first—was the egg first created, out of which the first chicken came, or was the hen the first to appear, and then to lay an egg?—and when we begin to investigate the origin of any animal, and to grope back to its first appearances, we make discoveries which are not only interesting and even astounding in themselves, but which explain much regarding the condition and appearance of the natural phenomena of the present day. In the case of our domestic animals, such an investigation, reaching away back into geologic times, explains

much in regard to their habits and instincts, and still more in regard to their comparative anatomy and suitability for different districts or "habitats."

The anatomical community of structure among the domestic animals may very well be exemplified in the study of the foreleg of each. All mammals have typically five fingers, or "digits," on each limb, though in some animals certain of these are wanting or in an undeveloped state. If these digits be numbered 1 to 5—No. 1 being the "thumb" or pollex—then their occurrence in our domestic animals may be tabulated thus :—

Horse	0	0	3	0	0
Ox	0	2	3	4	5
Sheep	0	2	3	4	5
Pig	0	2	3	4	5

To those who have no previous knowledge of comparative anatomy it may come as a surprise to learn that while the horse has only one toe on each foot, there are two more present in an undeveloped state, represented by the "splint" bones, out of sight below the skin and tissues.

The explanation of this and much more is to be found in the ancestry of the animals, the palæontology of our live stock, and the following chapters will be mostly devoted to a study of the same.

Whatever opinions may be held by the general reader on the subject of Darwinism, there is, in the writer's opinion, no room to doubt that it is a fact that all our domestic animals—*i.e.*, horses, cattle, sheep, and pigs—are descended from a common ancestor. At any rate, this conclusion is accepted by an overwhelming majority of those who are competent to form an opinion on the matter. There has been from time to time great outcry made with regard to the "missing links" in the descent of the human species; but in the case of the horse, the most, if not all, of these links have been found, and the chain is more or less complete. The same cannot, of course, be said of the other animals, but their descent can be inferred from analogy, and the gaps in the same are getting more and more filled up as time goes on.

Among our domestic animals there has been a surprisingly small amount of change—from a species point of view—within the historic period, or for even an unknown length of time before that. The horse is much the same as his ancestors were in

Pleistocene times ; the urus and the Celtic ox are still the types of our cattle ; sheep have developed most in their wool to the elimination of hair ; and swine have varied principally in the direction of fatness.

But when we come to study "breeds" it is quite a different matter, for within the last 1,000 or 1,500 years there has sprung up such a vast diversity of breeds within our Islands as cannot be matched elsewhere on the surface of the earth on an equal area. That the complex geological structure of these Islands is at the bottom of this divergence is the belief of the present writer, and part of this inquiry will be devoted to showing what this influence is, and in collating breeds to formations, or groups of breeds to groups of formations.

THE HORSE.

The line of succession begins in Eocene times ; there is a great gap or unconformity between the Mesozoic and the Kainozoic, which may have representative deposits with intermediate forms of life included therein in some of the unexplored regions of the earth, but the first recognisable ancestors of our live stock are found in Eocene deposits.

The ancestry of the horse has been most fully worked out by Marsh in America, for, indeed, it is in that country that the greater number of the intermediate forms have been found. Horses were extinct on both the American continents when invaded by the Spaniards so many centuries ago, but those that escaped from the control of the incomers agreed so well with the circumstances around them that they have multiplied amazingly, and unnumbered mobs of mustangs and other varieties of wild horses are, or were, roaming at large. It is one of the mysteries of the past that horses should have reached such a stage of development in comparatively recent times : have died out so completely that the Mexican Indians of the time of Cortes did not know what they were, and were afraid of those introduced, and named them the "animals with one toe nail" : and then have thriven so well when reintroduced within historic times.

Not only do we find the whole chain of descent more or less complete in America, from the earliest form down to the *Equus caballus* of the present day, but there have been found the remains

of true horses of a gigantic size in South America, showing that food and climate both suited the development of the race; yet, in spite of this, it became extinct.

Marsh stated* that the oldest ancestor of the horse, then undiscovered, undoubtedly had five toes on each foot, and probably was not larger than a rabbit, perhaps much smaller. This hypothetical predecessor of the horse he predicated with certainty from what was known of the early hoofed mammals. He called it the *Hippops*, and expected its remains would be found at the base of the Tertiary, or more likely in the latest Cretaceous.

An animal has been found in the oldest Tertiary deposits in America which almost fulfils the expectations of Marsh and Huxley. This has been named and described by Cope as the *Phenacodus*. The skeleton shows an "extremely primitive or generalised structure—as much so, indeed, as in any known mammal. The teeth had very short crowns, with tuberculated surfaces, and were adapted for an omnivorous diet. There were five toes on each limb, which carried hoofs at the extremities. The head was very small, and the size and shape of the brain cavity indicated a low state of development of the organ it contained."†

The most ancient corresponding form known in Europe—from the Lower Eocene—is the *Hyracotherium*, and from this most, if not all, of the Euro-Asian ungulates seem to have been descended. This animal ranged in size from that of a hare up to a fox, but the most important points about its anatomy are the existence of four digits on the fore limb and three behind, each terminated by a *hoof* as distinct from a nail or claw, and each in functional use, *i.e.*, reaching the ground, or nearly so; while the remaining digits are represented by "splint-bones" attached to the others. Another great point about its anatomy was the existence of the full complement of forty-four teeth; these were of the omnivorous type, *i.e.*, with small cusps not so elevated as in a carnivorous animal, but more so than in the flat grinding faces of a true herbivore, where the masticating speciality lies in the convoluted edges of the enamel. The premolars differed in size and shape from the molars, and were set in the jaw with spaces between them; one of the changes gradually evolving down the line

* Marsh: "Recent Polydactyle Horses." *Am. Jour. Sc.*, 1892, p. 351.
† Flower: "Evolution of the Horse." *R. A. S. E. Journal*, 1890, p. 115.

of descent being the closing up of these spaces and the approximation of these premolars to the true molars in size, shape, and appearance. The teeth, as a whole, had a further modification in that there was a gap or diastema between the incisors and the premolars—a gap that was taken advantage of when man appeared on the scene and invented bits, bridles, and the cruel and unscientific bearing-reins. It is just possible that if this gap had not appeared in the *Hyracotherium* it would not have existed in the horse or other domestic animals, and that the taming of the same would have been a great deal more difficult, for every horse then otherwise would have been able to take his bit in his teeth.

Following the *Hyracotherium*, the first genus to show equine characters was the *Eohippus*. This oldest and most diminutive form was about the size of a small fox. There was a space between the canine and the first premolar, but the premolars themselves had partly closed up, all of which were unlike the molars, while of course the animal was an herbivore, from its small canines and the flat grinding surfaces of the permanent molars. On the forefoot there were only four of the digits developed, while the first, or pollex, was reduced to a splint-bone—very probably buried out of sight in the tissues in the living animal. On the hind foot the pollex had entirely disappeared, and the fifth digit was reduced to a splint, leaving only three functional hoofs. Next in order comes the *Heliohippus*, the known representatives of which were about as large as a full-grown fox. This genus had a space between the first and second premolars, and the last premolar (No. 4) had become like the ordinary molars. In the limbs there was a further tendency to suppression of the extra digits, together with some other modifications.

The genus next in the line of succession is the *Orohippus* from the Middle Eocene. In this there are no spaces between the upper premolars, while the third and fourth are similar to the true molars. The ulna is large, and reached down the whole length of the radius, and the fibula also reaches the whole length of the tibia. In the forefoot the pollex, or thumb, is quite gone, the fifth digit becoming smaller and more functionless, while in the hind foot only three digits appear, the first and fifth being completely gone, not even represented by splint-bones. The animal was similar in size to the preceding.

Allied to the *Orohippus* is the *Epihippus*, which shows no space between the first or second premolars above or below, and the third

and fourth are essentially like the true molars. It was somewhat larger than the *Orohippus*, with some differences in the dentition and feet intermediate between that and the next form—the *Mesohippus*.

At the base of the Miocene beds the next type in the line has been discovered and named the *Mesohippus*. It was about the size of a sheep, and the fifth digit is represented by a splint in the forefoot, with only three middle digits left in the hind foot. There is no space between any of the premolars, and the second, third, and fourth are like the true molars. The ulna or elbow-bone is still complete, though much finer and thinner than in the *Orohippus*, while the fibula no longer reaches the full length of the tibia, but is reduced to a loose, splint-like bone.

In the Upper Miocene we come to the *Miohippus* (*Anchitherium*), an animal much larger than the *Mesohippus*, and more specialised in the skull and feet. The premolars form a continuous series, without any spaces between them, and the second, third, and fourth are of the molar type. In the forefoot the fifth digit is reduced to the merest tag of bone, and in both feet the second and fourth digits are becoming reduced and functionless, with a corresponding enlargement and development of the central one. The ulna is shorter and more adherent to the radius, while the fibula still more approximates to the condition of a loose splint.

In the early Pliocene we come to the *Protohippus*, the European equivalent of which was the *Hipparion*, or a variety of the same. The three toes on each foot are still present, and more or less functional. The animal was as large as a donkey and more nearly approximated to the horse type than the preceding forms.

In the later Pliocene we have the *Pliohippus*, which very nearly approximates to the horse of the present day, though smaller in size. The side digits are reduced to splints buried in the tissues in both fore and hind feet; the ulna reaches only half way down the radius, and is ossified to the same, while the fibula is a still smaller spike of bone, partly adhering by ossification to the tibia, while the incisors have the characteristic "pit" or infolding of the enamel which, in the modern horse, is the cause of the "mark of mouth," by which the age is judged. This peculiarity is not found in any other mammal, and it is not found among the ancestors of the horse until we come down to this comparatively recent form.

In the latest beds of the Pliocene, the true horse (*Equus*) appears with a largely developed central digit on each limb,

composed of the highly specialised hoof, pastern, and all the bones, ligaments, and other tissues, the care of which forms so large a part of the work of the farrier and veterinary surgeon. The second and fourth digits are represented by the small splint bones buried out of sight in the tissues covering them—the seat of the painful splint lameness which gives so much trouble to those who live by handling horses. The ulna is shortened and more or less completely fused to the radius—at least in old animals—while the fibula is reduced to a spike of bone reaching two-thirds down the tibia, and may be partly fused to it. The teeth have the deepest seating in their sockets of the whole of this series of animals, while the enamel plates of their grinding surfaces reach the highest degree of convolution.

These gradual changes down the series will be best understood from the accompanying illustrations, which were originally prepared by Marsh and Huxley, and are here given in a slightly modified shape, only the more important intermediate forms being given. (Fig. 9.)

Now, while the chain is pretty complete in the case of the horse, it may frankly be acknowledged that there are many gaps in the same, and that much of the evidence is inferential. In the diagram it is not meant that the *Miohippus*, for instance, was the foal of the *Mesohippus*, for the reason that possibly, and indeed probably, a million years intervened between the times of their existences, but it is meant that the latter is in the direct line of descent from the other, and further fossil discoveries are continually being made of intermediate forms. In fact, between the *Eohippus* of the Eocene deposits and the *Equus* of the present day some twenty to thirty intermediate forms are known and named. Some of these may be synonyms, and some may be contemporary variations, such as we have at the present day where a Shetlander and a Shire may stand together in the same stable ; but, all the same, the line of descent and the evolution from the oldest to the latest is continuous through some or all of these forms, and further discoveries made from time to time confirm this inference, and, so to speak, fill in the gaps.

We come back to the hypothesis, therefore, that the ancestor of the horse was a small animal with five functional digits ending in hoofs on each limb, and that by evolution and development the modern horse, with one functional toe only, became evolved through countless intermediate forms. If this belief rested only on scientific

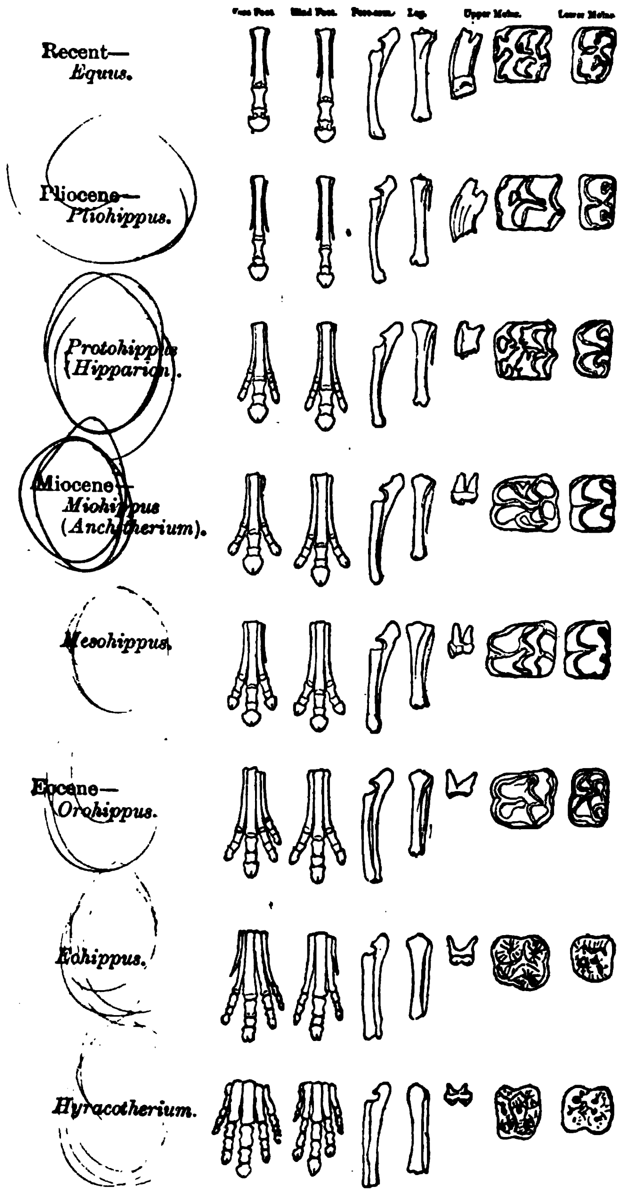


FIG. 9.

DESCENT OF THE HORSE.

inference it might be doubted by some, but it so happens that there is a large amount of evidence from the historical period to corroborate it, and cases bearing on the same may now be cited. Alexander the Great had a famous war horse known as Boukephalas (Bull-headed), which was remarkable in many respects. Tradition asserts that this animal had extra digits on each limb, *i.e.*, some of the splint bones had small half-developed hoofs on them like those on a cow or a sheep; that he had a wild vicious disposition, defying everyone to back him or break him in until Alexander did it as a feat of horsemanship while a lad; and that his head was large in proportion to the size of his body—if his name were derived from this, and not from the custom of branding a bull's head on the forehead; all pointing to the fact that the animal was not a true horse at all, but a reversion to the ancestral type of the *Pliohippus*, or even the *Hipparion*.*

Again, Suetonius, in his life of Cæsar, describes how that leader had a horse of his own breeding "which had feet that were almost human, the hoofs being cleft like toes."† This animal, from its description, must simply have been another case of reversion to the palæontological forms, and an additional proof of the truth of the continuity of the line of descent. Again, about the middle of the eighteenth century there was a multiple-toed horse exhibited at the fairs about the Midlands of England; while, coming down to our own times, Marsh‡ has collected several instances of horses of this type occurring in America, and known by such names as "Clique, the Horse with Six Feet," "The Eight-footed Cuban Horse," and the "Horned Horse of Texas." (Fig. 10.)

The normal and standard number of teeth for every mammal is forty-four—that is, in each half-jaw there are three incisors, one canine, four premolars, and three molars, the dental formula being—

$$\frac{3\text{—}4 \mid 1 \mid 3\text{—}3 \mid 1 \mid 4\text{—}3}{3\text{—}4 \mid 1 \mid 3\text{—}3 \mid 1 \mid 4\text{—}3}$$

The horse has only forty teeth, and it is a most interesting point regarding the tooth in each ramus which has disappeared. This is the first (non-deciduous) premolar, and the continuity of the line of descent is shown by the occasional appearance of this tooth in

* Schmidt: "Mammalia," p. 207.
† Suetonius: "De Vita Cæsaris," LXVI.
‡ Marsh: "Recent Polydactyle Horses." *Am. Jour. Sc.*, 1892, p. 340.

some individuals in a small form, known to horsemen as the "wolf's tooth." In old books on veterinary science directions are given for its removal when it showed itself, on the plea that its extraction helped the eyesight. Nowadays we know that its

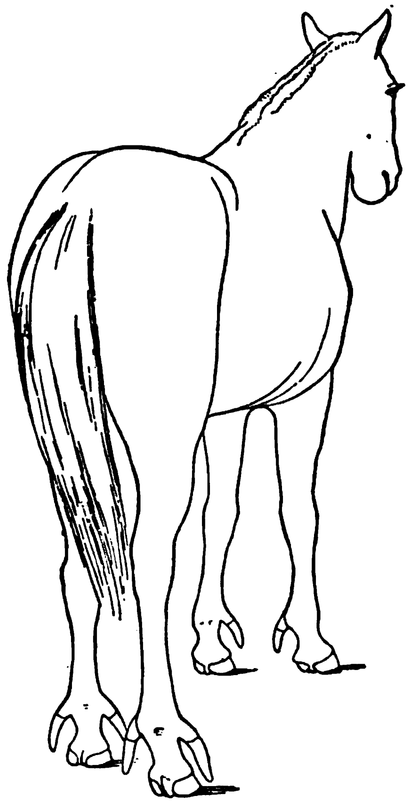


FIG 10.

MARSH'S TEXAN "HORNED HORSE."

occurrence is normal, and that its disappearance has been gradual during the sequence of forms of the horse kind anterior to those of the present day, while coeval with its disappearance the remaining premolars became enlarged and took on the characters of the

permanent molars, until what is now the first premolar (*i.e.*, No. 2 originally) is the largest tooth in the horse's head.*

One very noticeable development through the series of animals is that of the length of the teeth. In the earlier forms, such as the *Miohippus (Anchitherium)*, the crowns of the teeth are very shallow (brachydont), but become elongated more and more in the successive series until, in the modern horse, they reach the "high-toothed" form (hypsidont). The practical object of this is to supply a sufficient amount of body in the tooth to make up for the continual wearing of the grinding surface. The whole tooth gradually pushes up in its socket, and thus maintains the grinding edge constantly at the same level until the limit is reached. This modification gives the animal great powers of mastication, and enabled the horse and his immediate ancestors to live on the comparatively dry harsh herbage of the open plain—and to trust to his speed and kicking power for safety—in contradistinction to being limited to the soft and succulent herbage of the marsh and forest, or to depending on skulking in swamps and thickets for safety, as exemplified by the tapir or the wild boar of the present day. This, indeed, is another of the modifications which were gradually evolved through all the successive generations by which the horse became more and more fitted for the use of man; for if these and other developments had not taken place the animal would have been of as little use for the purposes to which he is now put as a tapir or a deer.

In a state of nature a horse's safety from enemies lies first in his speed and secondly in his kicking power, while his natural habitat is the wide, open plain or steppe, where he is secure from sudden attack. If attacked by an enemy horses seek safety in flight, and under ordinary circumstances could outrun any animal like a leopard or a lion; while, as they usually go in mobs, if attacked by a pack of wolves they form into a solid mass with their heads inwards and their heels outwards, the stallions on the outside, and thus present a solid phalanx of deadly hoofs to the enemy, a stroke from any one of which would lay open the skull or chest of a wolf. Cossack troops in Russia, if caught by a pack of wolves while on the march, have taken advantage of this instinctive action of their horses by forming them up into a circle with their heads inwards, and then sitting round with their faces astern, have

* Schmidt: "Mammalia," p. 210.

poured their shot into the surrounding wolves from a position of comparative safety.

In spite of this ability to cope with enemies, however, there is a great likelihood that horses as wild animals were exterminated, and that only those which were under the protection of and in use by man were saved alive. It is a notable fact, at least, that though horses have thriven tremendously in a feral state in both the Americas in our time, they had become extinct there before the historic period. In bygone æons they attained not only immense numbers, but also immense size—as true horses—and their extinction, taken in conjunction with the present suitability of these continents for their existence, is one of the puzzles of geology. A possible solution is suggested above—that is, that they were exterminated by the carnivora ; at any rate, it has been pointed out that pumas have a great predilection for horse flesh, and the inference is that horses were exterminated by them in the Americas anterior to the advent of man. It must, of course, be allowed that there is evidence to show that wild horses roamed over the plains of the Plate River before the advent of the Spaniards—that they were there when the Spaniards came—as inferred from the map of Sebastian Cabot, prepared in 1527–47, while Heilprin affirms* that the ancient horse was contemporary with man in South America; but Cabot's map appears to be the only evidence on this head. In the same way it is inferred that horses were exterminated in the Old World with the exception of those directly or indirectly under human control, though Heilprin says they have roamed over the European steppes since the early Quaternary period. As corroborating the belief in their extinction, there is the circumstance that it is a disputed point whether or not there are any truly feral horses in existence now, or which have been in existence in recent ages—either historic or prehistoric.

In Western Asia and Eastern Russia there has been found a variety of the horse *(E. Prjevalskii)* which is considered by some writers to be an aboriginal feral form—a truly wild form never interfered with by man—but again this is controverted by others, as there is the possibility that it is descended from "escapes" in bygone ages, its existence being indirectly helped by the neighbourhood of roving tribes of men tending to keep the carnivora in check. Some animals of this breed are now in the Zoological

* "Distribution of Animals," p. 370.

Gardens in London and elsewhere, and show the rusty dun colour and dark "points" we sometimes find in nondescript cross-bred ponies produced at home, and the colours and markings of which we look on as a "reversion" to the ancestral type.

In comparing the horse of the present day with his ancestral forms, the principal changes noticeable are as follows :—The neck has become elongated ; the skull altered in form ; the teeth greatly modified ; and a remarkable change has taken place in the limbs and "feet"—the greatest modifications having been in these latter.

Seeing that the horse has passed through so many and such tremendous changes in the way of evolution, the question naturally arises whether this evolution is now finished or if it has still further to go. Biologists are for the most part agreed that there will still be some further changes, and it is the opinion of several that as ages roll on modifications will continue to appear. The splint bones will disappear or become permanently fused as "processes" to the shank bones ; the small bones of the knee and hough which correspond to the above will also disappear ; the lateral cartileges will become permanent "side bones"—at least in the heavy breeds like Shires and Clydesdales ; the bones of the sternum or breast-bone will become fused into one, also the pelvis and sacrum ; the racer will become longer in the legs and neck ; the draught animal shorter and more massive in the limbs ; while all breeds will become more docile and more easily broken in.*

It is a curious fact that most of the fossil remains by which the ancestry of the early horse has been worked out have been found in lacustrine formations in what is now the territories of New Mexico, Wyoming, and Utah. Similar animals must have existed in other parts of the world, as, indeed, there has been found a tremendous accumulation of fossil bones—including those of the later forms of the horse—at Pikermi, in Greece, the Archipelago in bygone ages having apparently been a great grassy plain, where immense numbers of ungulates found a suitable habitat ; while the bones of the *E. stenonis*, an early European form, have been found in lacustrine deposits and kitchen middens in thousands, having been used as food by early man. But in America, from Escholtz Bay in the north to Patagonia in the south, remains of fossil horses are exceedingly plentiful.

---

* Hayes : *Live Stock Journal*, December 1st, 1893.

There are now six existing species of the horse kind recognised, classed as follows :—

1. The horse, *E. caballus.*
2. The ass, *E. asinus.*
3. The wild Asiatic ass, *E. hemionus.*
4. The quagga, *E. quagga.*
5. The dauw, or Burchell's zebra, *E. Burchelli.*
6. The mountain zebra, *E. zebra.*

All of these will interbreed with each other in a state of domestication and captivity, but they have apparently now reached that degree of differentiation that the cross-bred progeny or mules will not breed among themselves, though occasionally a female mule has been known to breed with the male of either of the pure species from which it was derived.* The work of Cossar-Ewart in this line is well known, and only needs to be mentioned here.

It is rather curious, however, that out of so many species only two have been domesticated by man during all the ages, and that the others should still be as wild and uncontrolled as their ancestors were.

It is a remarkable fact that among the remains of fossil horses, and even those found as late as the Roman occupation, there is no evidence of the diseases of the bones of the limbs, such as are not only common but almost universal nowadays. Roads did not exist as we now know them, and roadsters were walked or trotted on the grass, and there was none of the "'Ammer, 'ammer, 'ammer on the 'ard 'igh road." We thus find no trace of splints, spavins, founder, navicular disease, and the other troubles so common in our day. There is, however, one fossil canon-bone in the Geological Museum in London which has excrescences on exactly the spots where ossification takes place after splint lameness, and is, therefore, suspiciously like what horsemen call a "splint."

There does not appear to be a division of the immediate ancestors of the horse into more than one species—*E. caballus*, and all our domestic breeds and varieties are considered to be descended from this one kind. As far as Great Britain and Western Europe are concerned, however, this had been differentiated into several distinct varieties or breeds within or at the beginning of historic times. At any rate, there is evidence to show that there were at

* Flower: "The Horse." *Brit. Encycl.*

least three groups or varieties of horses in these Islands after the Norman invasion. These three may be classified as—

Celtic,	Flemish,	Norman,

and from these all, or nearly all, of the different native varieties have been evolved during the last 800 or 1,000 years.

The Celtic is a general name, of course, embracing all those descended from the aboriginal horses of Britain, which were here when Cæsar invaded the country, but not necessarily those with which Cassivelaunus and his ancient Britons pulled their scythe-wheeled chariots, for a reason which will shortly appear. Naturally we find the descendants of these where we find the Celtic races of men—to the west and north, or to be more exact, in the rugged and mountainous regions formed by the Devonian, Silurian, Cambrian, Granitic, and other forms of the Primary or indurated rocks. The names of most of these will be self-explanatory, and may here be given :—

Dartmoor,	Galloway,	Shetland,
Exmoor,	Highland,	Connemara.
Welsh,	Orkney,	

Some of these—as the Galloway* and the Orkney—are extinct or merged into others, but, on the other hand, there have been many other varieties never named or described, and now lost sight of, and which either were or could have been distinct breeds. Low, in his classic work,† says : "Over all the ancient wastes or forests of England, formerly covering the larger part of the surface of the country, were reared varieties of horses, the size and strength of which bore a relation to the quality and abundance of the natural herbage."

With regard to the Connemara, there is, of course, a doubt as to its Celtic ancestry. Low states‡ that it is descended from horses which swam ashore from the wreck of some ships of the Spanish Armada, and that both the colour (chesnut) and style proclaim it Andalusian. On the other hand, the natural inference is that if all the breeds of live stock reputed to have come from the wreck of

* "The Galloway is held to be still represented by the Island of Rum pony." Gilbey : "Ponies Past and Present," p. 17.

† "Domesticated Animals" p. 521.

‡ Ibid., p. 523.

the Armada *did* swim ashore, as tradition says, then the *Sanctissima Trinidada*, the "tall *Pinta*," and all the others must have been more like Noah's Arks than warships. In any case there must have been native horses in Connemara as elsewhere, and the incomers, if any, were only grafted on to this stock.

Cossar-Ewart has been investigating these animals, and reports that there are five varieties found in the district, one variety probably with Spanish blood, but the others mostly native—especially the Cliffden variety*—so that we are justified in saying that the Connemara pony is as indigenous to the Silurian rocks of Galway as the Welsh pony to the Silurian rocks of Wales.

It will be noticed that in the above list of "ponies" the New Forest breed has been omitted. This is simply for the reason that the author has not been able to get it to come naturally into any classification with the others. It is isolated in locality from the other breeds, its habitat is on recent geological formations, and in colour—though ranging through every variety—it seems to have a predominance of grey. Whether it has any connection with any breed of horses on the opposite coast of France—such as the Percheron—does not appear, but at the present stage of this inquiry we find it exceptional in many respects. There does not seem to have been any allied breeds in the South of England in ancient times.

It will be noticed that this class includes all the "ponies"—that is, animals under 14 hands or so, and comprising the small breeds. Ville has called attention to a well-known natural law† which explains this, that all animals developed on felspathic formations are diminutive; while, on the same lines, Hugh Miller, the geologist, in his essay on the Sutherland evictions of a bygone generation, pointed out that in Assynt "everything was stunted except the men." Felspar is a predominating constituent of the Primary and Igneous formations, while limestone is wanting, and a concurrent complementary law seems to be that you must have limestone rocks present in some form to develop good stock.

Of the Flemish tribe the Shire and the Clydesdale are the only modern representatives: both of large size, and both naturally thriving best on low-lying, soft, moist, alluvial, and fen land, similar in nature to the alluvial deposits of Flanders.

---

* *Live Stock Journal*, November 23rd, 1900.

† "Perplexed Farmer," p. 117.

Some of the extinct varieties of this may be mentioned. Thus we have had the Old English Black Horse, the Great War Horse, the Lincolnshire Black Horse, the Wildmoor Fen Horse, the Derbyshire Black, and so on, all of which were similar to, if not identical with, each other, but now represented by the Shire.

There is no reason to doubt that the Fens and Midlands produced large horses in the time of Cæsar, as well as did the Low Countries (with which there was much intercommunication even in those early days, from the fact that some of the British tribes were Belgians), because there is great similarity in the geological and physical features of the two regions. Cæsar was much struck with the appearance of the horses in the army of Cassivelaunus as being superior to those he was accustomed to see. Now the curious fact is that Cassivelaunus was chief of the tribe called Catieuchlani, occupying the district now comprising Cambridge, Northampton, Rutland, and Leicester shires, and forming a big slice of the country in which the large horses originated. A confederacy was formed to oppose the landing of the Romans, and Cassivelaunus was elected general, but, owing to the jealousy of the other chiefs, he was almost deserted when the tug of war came, and had to face the Romans with almost only his own tribe. Thus it comes about that probably the only horses Cæsar ever saw in Britain were the ancestors of our largest breed, and he never came in contact with the Celtic "ponies" at all.

Of the Norman horses there are several breeds of importance in the country, as follows :—

Cleveland Bay,	Norfolk Hackney,
Yorkshire Coach,	Suffolk Punch.

The notable features of resemblance among these four is, first, the fact that their habitat is along the eastern side of England, and on the higher and drier Secondary formations, and, secondly, that they are all of a chesnut or brown colour.

It is usual, of course, to class these as of Norse descent, because of their geographical position and the fact that some Swedish horses of the present day are chesnut-coloured; but on the other hand, the Highland pony, which has undoubtedly some Norse blood in him, has no tendency to similarity in colour and appearance; while the Normans, who were Norsemen originally, did infinitely more in the way of horse-breeding than the preceding invaders. Their horses, however, were mostly of Spanish

origin–chestnut Andalusians—the favourite charger of William the Conqueror being one of this sort,* and it appears, therefore, in the absence of direct testimony, that these animals owe most to the Norman invaders. This, however, is a debatable point.

It has been suggested by some† that the colour of the Cleveland Bay is due to having been grown for centuries on an ironstone soil, and that this also is the reason of the bay colour of the Exmoors. There probably is something in this as regards the last, while even as regards the first—though the colour is common to the Norfolk Hackney and the Suffolk Punch, grown where there is no special proportion of iron in the soil—the colour has been deepened by centuries of ingesting an extra proportion of iron compounds. It is worthy of notice in connection with this that a large proportion of Andalusia—the original home of the chestnut Andalusian breed—is on the Oolitic and Cretaceous formations, that is, the same kind of rocks that occupy the east of England from Suffolk to Cleveland. The author is not able to assert at the present stage of his inquiry if there is anything more than an accidental coincidence in this, but calls attention to the fact.

There is an exceedingly small amount of information extant regarding the origin and the varieties of ancient breeds of horses—for it is with regard to the evolution of these ancient varieties that we must look to see the influence of natural circumstances, such as geological formations. Besides the breeds above named—the most of which are extant yet—there may have been a score of other native varieties which never had a name outside their own locality, and which are now wholly extinct. The horses of to-day are largely the product of artificial selection in an artificial environment, and breeders can make a success with any given breed under conditions quite different from those under which it was originated. The Clydesdale is an example of this; some of the best animals have been bred in Wigtown and Kirkcudbright shires in our times, but the animal could never have been evolved there. The native horse of this stretch of Silurian country was the Galloway—now extinct there, at least—an animal very much smaller than the Clydesdale, and more like the Welsh, which has been developed on similar geological formations. It is doubtful even if the Clydesdale as we now know it would ever have been developed if

* Youatt: "The Horse," 4th Ed., p. 56.

† Kerr: *Live Stock Journal*, October 28th, 1887.

it had not been for the interference of man in crossing the native Lanarkshire animal with some of the Flemish blood of the Great Black Horse, the War Horse which carried the knights of old when loaded with armour.*

The author can even go further, and affirm on geological grounds that the Upper Ward of Lanarkshire never would have produced a big horse any more than any other district in Scotland had not at some early period the blood of a big breed been introduced from without—the blood from which the Shire horse has been contemporaneously evolved. At what period this blood was first introduced into Scotland we have no means of finding out, but there is one explanation which naturally suggests itself. Clydesdale was one of the routes generally taken by the invading armies in the old fighting days. English knights rode big stallions; when a knight was killed his horse would be captured if it were not allowed to run wild. The native Scots then did not object to the use of good sires any more than their descendants do now—especially when there was no premium to pay; and thus we believe the Clydesdale horse was evolved by crossing with the native "garrons" long before anything in the shape of systematic breeding was attempted—probably, indeed, before the time of William the Lion in 1214. There appears to be evidence that the Flanders stallions captured by Bruce from Edward at Bannockburn were the first ever advisedly used for breeding purposes,† but since then there has been a long series of importations of Flemish blood down to our own times, whereby the modern Clydesdale has been built up, and built up in spite of adverse natural conditions.

The native natural horse of any district is the outcome of two factors: first, the original variety or breed from which he is descended, and, secondly, the influence of soil, climate, food, &c., on his development during, say, a thousand years; and the difference between this and the methods which have been adopted to develop our modern artificial breeds must be taken into account in studying their evolution from a geological and palæontological point of view.

Even the "original variety or breed," if it can be traced to its beginning, will be found to have been influenced or "developed" by the geological conditions of its habitat.

* Gilbey: "The Great Horse," p. 26.

† Craig: "Paper read before Eastern Counties Dairy Association," February, 1899.

Regarding this geological influence on the development of horses, Low has a noteworthy passage,* which we quote entire, and which may conclude this part of the inquiry. It is all the more noteworthy because it was written over half a century ago: "When we compare the coasts of Britain with those of the opposite continent, we find a striking similitude in their geological formation, and in their animal and vegetable productions. All along the British Channel, from Land's End to the Straits of Dover, we have a country resembling, even to the indentations of the coast, the countries of France from Ushant to the Pas de Calais. Bending northward, the flat alluvial countries of the eastern coast of England correspond in the closest degree with the lowlands of Belgium and Holland. The marshes of the Zuyder Zee seem to be reproduced in the fens of Lincoln, and in both localities the horses resemble one another, even to the colour of the skin. Stretching again from the Humber northwards, the country in England corresponds with the Danish dominions of Holstein, Sleswick, and Jutland, and each locality produces horses tall and strong, where circumstances favour the development of their forms, of diversified colours, and differing from the great horse of the marshes; and we might pursue the parallel until we reached the granitic mountains of Norway and the Scottish Highlands."

* "Domesticated Animals," p. 614.

CHAPTER XII.

THE EVOLUTION OF LIVE STOCK.—II.

THE OX.

The geological history of the ox—as, indeed, of the other kinds of live stock—has not been worked out as fully as with the horse, and the various known fossil forms only yield us fragmentary evidence of the line of descent. It is not, indeed, till we come to late Miocene and early Pliocene times that we can recognise an animal of the ox kind—the *Bos planifrons*, the polled ox of Rutimeyer,* to be followed in the Pleistocene by the two forms which have held to the present day—*Bos urus* (or *primigenius*), and *Bos longifrons*. The ruminating ungulates developed horns in Miocene times, and towards the end of that age the antlered type became differentiated from that with horns proper†—the latter including all of the "cattle kind," such as bisons, buffaloes, &c.—and it was later still that the ox branched off, so that we arrive at the beginning of the Pliocene before we have an animal approximating to the domestic cow of the present day.

The origin and evolution of horns and antlers—more especially in connection with our domestic animals—is a study of absorbing interest.

The original ungulates were polled or "bald"—*i.e.*, they had neither horns nor antlers—but as we come down the line of descent we find these becoming more and more in evidence. Darwin held that these growths were the result of sexual selection and the sexual strife of rival males, but was not quite satisfied with his own explanations, while more recent studies have shown that both horns and antlers have very little to do with settling the battles among bulls, bucks, or rams. Often and often it is a polled animal that is "cock of the walk": a Galloway can best a Highlander, and a Leicester tup can capsize a mountain Blackfaced one. To

---

* Schmidt: "Mammalia," p. 178.

† Ibid., p. 181.

make a long story short, the existence of these frontal appendages are due to the survival of the fittest in the struggle for life with carnivorous opponents during the long ages of the Tertiaries. It is a fact that in the earlier ages all the ungulates were without these protective growths; that they appeared in a small way at first and gradually became of greater size and more importance till they culminated in such specimens as the *Bos antiquus*—measuring twelve feet from tip to tip of horn round the curve—and the gigantic misnamed Irish elk (*Megaceros Hibernicus*); while contemporaneously the *Felidæ* and *Canidæ* waxed greater and greater till we meet with the sabre-toothed *Machairodonts*—animals like tigers in general appearance, but much larger in size, and with recurved serrate-edged teeth—perhaps the most terrible carnivorous animals the world has ever seen, but fortunately extinct before the advent of man. Contemporaneously with these again from age to age we find a gradual extinction of the ungulates unprovided with these protective organs; the carnivorous animals, as it were, fed on those they could catch most easily, and which were least able to fight for life, until they almost exterminated them; and thus of the many genera of unprotected "odd-toed" animals of this sort once in existence only three survive—the horse, the tapir, and the rhinoceros.* The two latter have survived from evolving modes of life or thickness of hide which were protective—though even the rhinoceros has found it necessary to develop a horn or horns on his snout—but in the case of the horse it is just possible that total extinction would have supervened if man had not appeared on the scene and taken the brute under his protection.

The success of polled or bald males among the ruminants in sexual warfare proves that their frontal appendages are not of great use in this direction, and, indeed, if the fighting between bulls or rams or stags be watched, it will be seen that it is the butting or battering tactics which are adopted, and that their weapons rarely come into use at all, or only when one yields and is chased by the other. It has, indeed, been estimated that only one in two hundred stags are killed in combat,† while if their antlers were used as they are against enemies, they would exterminate one another in a short time.

---

* Cameron: "Horns and Antlers of Ruminants." *Zoologist*, August, 1894, p. 249.

† *Zoologist*, August, 1894, p. 285.

That horns and antlers were evolved to meet the development of carnivorous animals in Middle Tertiary times is proved by the deadly use the possessors of the same can put them to nowadays when attacked by wild beasts. "The herding bison is more than a match for the wolf, and the herding buffalo for the tiger; the herding antelopes could hold their own with the lion, and will rescue a calf from the armed hunter; and among the herding deer, when danger threatens, it is the master stags that take the lead."* The buffaloes of Asia and Africa are a match for the largest felines of their respective continents, and even the slender horns of the little Indian blackbuck give pause to so formidable an opponent as the hunting leopard.†

The evolution of the polled cattle in recent geological or prehistoric ages is a little bit of a mystery. The earliest fossil remains show polled animals (*Bos planifrons*), both male and female, but it is certain that hornless animals would stand little chance of survival in an age or country where carnivorous animals were common. Polled breeds, therefore, must have been evolved in comparatively recent times—though they are a reversion to the early type—and "fossil" skulls of this kind must be looked on with suspicion.

Antelopes have been associated since Pliocene times with the feline carnivora of plains and deserts, deer and oxen with the canine carnivora of forests and hills: thus the gemsbok kneels to receive the attack of the lion with lowered head and spiky horns, while, on the other hand, the antlered deer swings his head from side to side before a pack of dogs.‡

The assertion that the ancestors of the ox have had to fight most in bygone ages with wolves and other canine carnivora is corroborated by the instinctive antipathy which a herd of cattle have to a dog, especially a strange dog. The appearance of one in the field where they are grazing—even if it is the collie that belongs to the farm and which they see every day—is the signal for heads up and "attention," while most likely they gather together and chase the intruder out. A cow with a calf is especially apt to attempt to attack any dog that comes near; and so it is a rule on the farm to keep such away from animals at parturition time, or when a young calf is in its first helpless stages. Thus the habits

---

* *Zoologist*, August, 1894, p. 291.
† Ibid., p. 250.
‡ Ibid., p. 282.

of ancestral fossil forms acquired in Miocene and culminating in Pliocene times have lasted to the present day, and affect the farm management of the twentieth century of the Christian Era.

Conversely, it might just here be pointed out that the instinctive hunting, setting, pointing, and driving power of the dog kind—which has attained its highest and most useful development in the sheep-collie—is simply the natural instincts of the hunting carnivorous wild dog or wolf of these far-away ages, which have been trained and modified by man through almost countless centuries to produce the result we see at the present day.

Leaving now the subject of the evolution of horns, we find, as already pointed out, that in the development of our domestic breeds of cattle there was a period in their history when there were only two varieties, breeds, or species. These two were known respectively as the *Bos primigenius* or Urus, and the *Bos longifrons* or Celtic Ox; and the style of their horn cores, frontal bones and eye sockets is illustrated in the accompanying diagrams. The first is, geologically, the oldest animal, and we may first make some remarks regarding the same. (Figs. 11 and 12.)

In our own country the urus was the contemporary of the mammoth, rhinoceros, cave bear, and many others associated with these in recent deposits. It must have attained a gigantic size, because remains have been found which indicate a length of 12 feet and a height of 6½ feet at the shoulder when alive. Cæsar and Pliny speak of it as being common in the European forests of their day, and hunted by the German tribes; and this is, perhaps, the first notice we have of it in written history, though we know from the fossil remains that it was in existence in prehistoric times.

It attained its greatest development in Pleistocene times, and this is, perhaps, due to the fact that it must have had an enormous extent of continent to roam over, while possibly the coexistence of large carnivora had something to do with the development of its size by killing off the smaller and weaker individuals.

It was probably completely extinct in England at the time of the Roman invasion, and has, indeed, not been found in any remains later than the refuse heaps of the Bronze Age, for we do not find it in any of the more recent beds of Britain or in any of the kitchen middens of the pre-Roman inhabitants, or of the time of the Roman occupation, while Cæsar does not mention its existence, though he speaks of it as common on the Continent. The inference is that after the separation of these Islands from the

Continent at the close of the Pleistocene age, it began to dwindle in numbers as we know it dwindled in size, until, by the beginning of the Christian era, it had either become extinct altogether or very scarce, and confined to remoter parts of the country. Actual extinction would best accord with all the known facts, though it

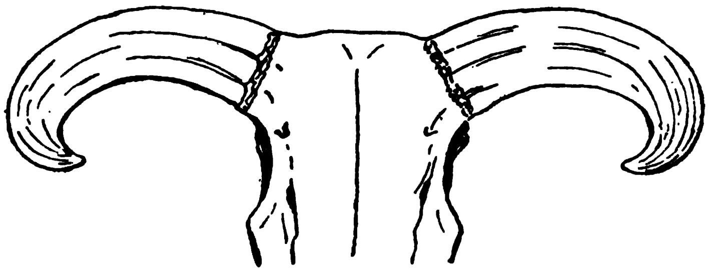


FIG. 11.

HORN CORES OF *Bos urus*.

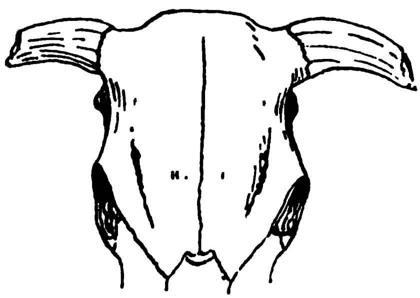


FIG. 12.

HORN CORES OF *Bos longifrons*.

continued to live and thrive and become domesticated on the Continent. When domestication took place we can only infer from more recent historical facts, while no doubt the process was rather a long one, and is by no means perfected yet in our own day. To put this matter of domestication shortly, it may be stated

that the present and former-day breeds of cattle of Germany and Middle Europe generally are held to be the domesticated descendants of the *urus*, and that the breeds or varieties known as Frisian, Holstein, Dutch, &c., are simply the modern representatives of it. Now, our English-speaking ancestors—comprising in this term the Jutes, Angles, and Saxons—which swarmed over from the Low Countries after the Romans had left Britain, brought not only their wives and families with them for purposes of colonization, but also their cattle, and thus animals of the *urus* type were reintroduced into the country, from which a proportion of the breeds now met with have descended. Further, some of these became feral again as "escapes," and continued to remain in the wild state to our own times, possibly forming the "tauri sylvestres" of William Fitz-Stephen, who wrote in 1174, and the "mountain bulls" of Sir Walter Scott. Their undomesticated descendants are represented by the "wild cattle" now confined to enclosures at Chillingham, Chartley, and Cadzow—cream-coloured cattle, with black or dark "points."

A great deal has been learned in our own days from instances in which domestic cattle have been allowed to run wild, and allowed to breed without the interference of man. In Queensland, for instance, the pure shorthorn has—when allowed to become feral—developed "black, brindled, and dun" offspring. If the shorthorn is of *urus* descent then this is evidence in favour of Dawkins' opinion that the *urus* was not of a white colour, but of a dusky hue.

Coming now to the other variety of cattle—the *Bos longifrons*, or Celtic ox—we have one which differed very much from the *urus*. There is no authentic evidence of this small "shorthorn" having existed in Europe in Pleistocene times. It was the domestic ox of the ancient Britons, as proved by the bones found in their midden-heaps, and it supplied beef to the invading and conquering Romans; while it is found round the dwellings and in the tombs of the Bronze Age, and back into the Neolithic or Stone Age, but no earlier. It does not seem even to have been living anywhere in Europe during the time of the pre-Celtic Esquimaux-like people who once occupied Western Europe.* It becomes a puzzle, indeed, to know where it came from or how it developed alongside of the gigantic *urus*. Anyway, at the beginning of the historic period it

* Dawkins: "Fossil British Oxen." *Jour. Geol. Soc.*, August, 1867, p. 183.

was the only breed of cattle known to our British forefathers, and when the Saxons invaded the country they drove the natives before them or killed them out. They do not seem to have even taken possession of the cattle, for they brought their own of *urus* type, while the Celts took their small shorthorns with them, and retired to Cornwall, Wales, and the Highlands of Scotland, &c., where, in the course of ages, the Celtic ox gave rise to the breeds of cattle now indigenous to the western and northern parts of these Islands. The warring of Saxon and Brit-Welsh covered many generations, during which the eastern side of the country became populated with animals of the Frisian type, while the Celtic type was wholly exterminated.

Professor McKenny Hughes, in his paper contributed to the Society of Antiquaries, in 1896,* takes a completely different view of the origin of some, at least, of our breeds of cattle. He accepts, in short, the *Bos longifrons*, but not the *Bos urus* ancestry, and substitutes for this latter the Roman cattle, introduced during the Roman occupation, and crossed with the native animal. He may be right in his argument that Roman cattle were introduced, and that the modifications in the horns and skulls of the Celtic ox found in those dug up among Roman remains were due to this crossing, though it is rather curious that among a plenitude of historians from Cæsar downwards, and with a nation which honoured and excelled in agriculture, no documentary evidence is forthcoming to prove this. On the other hand, so far as we can see, he does not give sufficient prominence to the fact that the German cattle must have a large proportion of *urus* blood in them, if not wholly of this descent, an assertion which is borne out by the locality they are found in, and by their characteristics—as will be gone more fully into later on; neither does he give sufficient weight to the historical fact that the Jutes, Angles, Saxons, and others of that ilk, who came over and settled in England from 449 A.D. onwards, came not merely in marauding bands, but *en bloc*, with all their "bestial" as well as their wives and children, and that they drove the Romano-British clean out before them, or massacred them if they did not go. It does not follow, of course, that they drove out or massacred the native cattle; and if the British left in a hurry they may not have been able to take their live stock with them. He is at pains to explain that the Romano-British tribes had improved and

* "Archæologia," LV., 1896.

unimproved stock side by side, and that they took the good ones and left the bad to their conquerors, which latter were foolish enough to allow these to cross with their own superior cattle. The author's opinion of this is that the incomers had an eye for a good cow, like other people, and that while they had no objection to use the beef of the semi-wild animals left behind, they would postpone the interbreeding process, and that this crossing to produce some of the breeds we now recognise was a much more subsequent operation, coeval with the mingling of Saxon and Celt in the subsequent centuries.

He also points out that the Roman cattle had upstanding lyre-shaped horns in contradistinction to those drooping forward on the *urus* type, and gives the Ayrshire as one of the present-day breeds most nearly representative of the Roman. It will be shown, in due course, that the Ayrshire has a large proportion of the *urus* blood in it; while, as a matter of judging by its horns, the learned professor is slightly off his eggs. The present horn of the Ayrshire is the result of a show-yard fad—an artificial type which has been followed now for a generation, to the personal grief of the writer. The original horn of the Ayrshire was the "crummie" type,* a nice little turned-forward, incurved arrangement, exactly in the *longifrons* style, and which was harmless as a weapon. Now, those breeders who have been smitten with the show-yard craze have—by selection, by the use of pulleys and weights, by the use of the rasp, and by the use of hot porridge poultices—so moulded and altered the horns that they are now as deadly as the horns of the gemsbok, which even the lion will not face. As an Ayrshireman, and a lover of a "guid coo," the author has done his little best to persuade his fellow-dairymen to revert to the original type of horn as a matter of safety, beauty, and utility, or even to introduce the polled type, but without success. That such was the old, natural type of horn is perfectly well known to the older farmers, and the writer can just remember it being common himself, while all the old prints represent it—as, for instance, in Raynbird's "Cattle" (1859) and Youatt's "Cattle" (1842)—while Low describes it as "small, and incurving inwards at the extremity after the manner of the Alderneys."† The annexed diagrams of the Ayrshire of 1840

* From the Irish *Crom-adharcach*, "stooped-" or "curved-horned" = English "crumpled-horned."—Wilde: "Ancient and Modern Races of Oxen in Ireland." *Proc. Roy. Irish Acad.*, 1858, p. 240.

† "Domesticated Animals," p. 343.

and of the present day illustrate the change, while it is easy to get examples with the horns still wider and more upset among our existing herds. (Figs. 13 and 14.)

Looking at Professor McKenny Hughes' evidence as a whole, one comes to the conclusion that we certainly do want something more definite than the set of horns shown on the ox head stamped on Roman coins, and the same on existing Italian cattle or ancient Egyptian cattle, to prove that the Romans introduced Italian breeds and crossed them with the native *longifrons* in such numbers as to permanently alter the type of the same. We know that, in our own time, we have seen the horns of Galloways dis-

FIG. 13.

AYRSHIRE OF 1840.

FIG. 14.

AYRSHIRE OF 1900.

appear in, say, a century and a half, and in one generation the horns of Ayrshires have been converted from one type into another —and made a fixed type—by the artificial interference of breeders; while the Ayrshire is given by him as an example of a Roman type and Roman influence. He seems to assume that the Teutonic strain was long-horned, and thinks it could not have had much influence because there is a scarcity or absence of long-horn bones in the refuse heaps of the early Mediæval Age. It was considered by Rütimeyer that the Dutch cattle in general, and the old Friesland breed in particular, were the nearest living approach to the *urus* type, and none of these are long-horned. Assuming that the

Shorthorn, the Holderness, the Suffolk Dun, the Fifeshire, and some others are of the same blood, the fact remains that none of these had large horns. Further, the *Bos urus* himself did not have large horns in proportion to his size. That size was no doubt immense—12 feet long from nose to rump, and 6½ feet high at the withers—and therefore the horn was of immense size to correspond, but it was proportionally smaller than that of the Longhorns of our days, or even than that of the Highlanders.

So far as the author can see, indeed, the large horn seems to have been a recent sport, peculiar to the limestone regions of both Craven and Connaught*; and which the great Bakewell unfortunately did not try to eliminate from his favourite breed, with the result that that breed has been nearly eliminated altogether for the sake of handiness and comfort to those who handle cattle and make their living by the same.

Such a large proportion of our animals of several breeds, however, have the upstanding or lyre-shaped style of horns, that we may grant some influence to Roman blood. These animals were presumably derived from Egypt in early times, and Professor McKenny Hughes jocularly suggests that their pedigree should begin with the famous bull Apis.

Finally, however, according to Dawkins,† the Roman ox in Britain was only a variety of the *Bos longifrons* anyway, so that we start after all with practically only two breeds of cattle in the fifth century of our era, and from these all our multitude of breeds have been evolved. To know where to look for each type among those in existence to-day, we must think where these predominated at, or shortly after, their various introductions.

The little Celtic ox was the only one in Britain at the time of Cæsar's invasion, and as the Roman occupation did not reach some parts of the country at all, and only partly dominated some others, we may look to these outer parts for a survival of the purely Celtic strain of blood. Thus, in Ireland, the Highlands of Scotland, some of the remote parts of the Welsh hills, and so on, we ought to find it. It has, indeed, been pointed out that the Kerry cow is probably the purest representative of it—a fact corroborated,

* In the American *Consular Report on Cattle and Dairy Farming* (Vol. I., 1887, p. 94.) the Longhorned breeds are affirmed to have been developed on phosphatic soil.

† "Pleistocene Mammalia." *Prelim. Treat. Palæ. Soc.*, 1878, p. 17.

not merely by history and geographical position, but by the general appearance of the animal itself. Similarly, the West Highland cattle (Kyloe), as distinguished from the larger Highlanders, come in the same category, as do also some of the Welsh breeds—especially some of the older local varieties—many of which are now extinct or modified.

As regards the size and set of the horn alone the Longhorn of the present day most nearly approximates to the *urus* type, and the Jersey to the *longifrons*, as exemplified in the illustrations. (Figs. 15 and 16.)

FIG. 15.

Bos urus TYPE (LONGHORN).

FIG. 16.

Bos longifrons TYPE (JERSEY).

Coming now to the other side of the country, we find, as already explained, that from the year 449 A.D. onwards for many generations, there was a constant influx of Teutonic tribes, bringing with them all their cattle kind This means that—granting that these cattle were of *urus* descent—there was a gradual filling up of the whole eastern seaboard of the country with cattle of this type ; and it matters very little whether the substitution of this strain for the Celtic or Romano-Celtic variety was slow or sudden, the result was the same—the eastern breeds are all of this variety, just as the western ones are of the other.

In what might be called the middle part of the country—north and south—the cross-bred blood would naturally appear, but not till the country had become more settled and the Celt and the Saxon had agreed to live side by side in peace, and

come and go in the ordinary affairs of life. Where any particular breed does not fall into this triplex arrangement there is some special reason for the exception—probably explainable by a reference to history. To put it shortly, the cattle—like other live stock—followed the fortunes of the tribes to which they belonged, and as each successive wave of invasion flowed from the east and crushed the previous inhabitants further to the west and north the specific varieties of cattle shared the same fate; and we look for each kind to predominate according as the races of men which have amalgamated to make the British nation predominate in one district or another.

The ordinary practical farmer of to-day who is acquainted with the existing varieties of cattle, and who is accustomed to see in numberless instances a special breed thriving and paying in a district far removed from its native or historical habitat, may be inclined to doubt this collation of breeds to their respective ancestors, special environment, or geological formations, but the reply to and explanation of this state of matters is the fact that domestication, artificial selection, and artificial care can go a long way to stultify the results of natural selection and modifications due to the influence of natural surroundings. The present perfection of breeds for the purposes of domestication would never have been arrived at by the action of natural surroundings alone. On the other hand, the specific characteristics of the various breeds have been imprinted on them during the fourteen hundred years or so which have elapsed since the time, say, of the first introduction of *urus* blood in the fifth century, and these influences were so great, and there was so little change or migration of the animals, that every district had its own special breed, not of cattle merely, but of all other kinds of live stock.

The plenitude of local breeds was commented on by Darwin, who affirmed that every district had its own breed of cattle and also of sheep indigenous to it,* and this will be best understood if a list is given of all those varieties of cattle we find mentioned by writers on live stock—more especially the older writers who studied them before the introduction of railways mixed up the country so much, and before the more prominent kinds, such as the Shorthorn for instance, had been introduced in fresh localities, and the aborigines allowed to die out. These are put into the three

* "Animals and Plants under Domestication," Vol. II., p. 210.

categories of Celtic, Teutonic, and Mixed, and this classification is adopted partly from a study of history, partly from local traditions, and partly from the appearance of the animals themselves—especially the set of the horns of each breed.

Our cattle, therefore, can all be classed on one or other of three types—*Bos urus*, *Bos longifrons*, and Mixed—and an attempt is here made to classify all those of which we know anything on this system. Modern breeds are small in number compared with those which existed long ago, for every district had its own variety in the days before railways enabled people to move about so readily, and before the systematic improvements in breeding took place. In the older works on live stock—such as those of Youatt and Low—mention is made of at least sixty breeds or varieties (though there were probably as many more), and these we classify as follows:—

Bos longifrons type—

Sutherland.	Cumberland.	Brecon Blacks.
N. Highland.	Anglesea.	Cornish „
Kintail.	Carnarvon.	Jersey.
Kyloe (W. Highland).	Cardigan.	Guernsey.
	Carmarthen.	Alderney.
Skye.	Pembroke.	Irish Moylè.
Galloway.	Merioneth.	Kerry.

Bos urus type—

Cadzow.	Lincoln Red.	Sussex.
Chillingham.	„ Dutch.	Dorset.
Chartley.	Craven Longhorn.	Glamorgan.
Fife (Falkland).	Derby „	Castlemartin Black.
Shorthorn.	Stafford „	„ White.
Teeswater.	Suffolk Dun.	Irish Longhorn.
Holderness.	Hereford.	

Mixed type—

Shetland.	Ayrshire.	Shropshire.
Orkney.	Lothian.	Montgomeryshire Smokyface.
Banff.	Ettrick.	
Aberdeen Horned.	Yorkshire Polled.	Old Gloucester.
Buchan Humlie.	Yorkshire Middlehorn.	N. Devon.
Angus Doddie.		S. Devon.
Forfar Horned.	Norfolk Horned.	Irish Middlehorn.
Argyle (S. Highland).	Red Poll.	

The names of the most of these indicate the locality where they were evolved, or where they predominated at one time, and if these habitats be compared with a geological map the following general facts will be noticeable. All animals of the *longifrons* type will be found on the old primary, indurated, rugged formations from the Devonian downwards—following, of course, the same rule as the Brit-Welsh or Celtic population with which they were originally associated.

The *urus* type again is to be met with on the newer and less indurated formations, from the Old Red Sandstone upwards—following, of course, on the lines of the original invasions and occupations of the country by Teutonic tribes, from the time of the Belgæ who held the southern shires when Cæsar landed on the coast of Kent till the advent of the Dutchmen who came in the wake of William of Orange on the sorting up of the British Constitution after the events of 1688.

Of the Mixed type it will, on examination, be found that all the Scottish mixtures have a predominance of *longifrons* blood in them, and all the English mixtures a predominance of the *urus*; that the former are found like their purer relatives on the old formations from the Carboniferous downwards, and the others (including the Irish Middlehorn) from the Carboniferous upwards.

The Ayrshire may be noted again as a specific example, partly because of the prominence given to her by Professor McKenny Hughes, and partly because the author likes the " beastie " himself. There is well-authenticated tradition, if not documentary evidence, that the native little Celtic " scrub " was crossed by the Kyloe, the Holderness, and the Alderney. This means that it is of at least two-thirds Celtic blood, while its original horn, before it was tampered with by people who did not know any better, was one of the most typical of the *longifrons* variety.

Occasion has been taken elsewhere to point out the influence of specific formations on individual breeds—such as that of the Carboniferous Limestone on the Shorthorn, and the Old Red Sandstone on the Hereford breed—and a few notes may here be added on the influence on cattle of geological conditions in other parts of the world. Take Eastern Europe by way of example :—From the Carpathians to the Urals there is an immense stretch of country 1,500 miles across and largely composed of one formation—the alluvium deposited by a great lake and underlaid by rocks of Permian and Triassic Age (especially in the province of Perm)—

and over this great stretch of country there is practically only one breed of cattle: the white cattle of the Russian steppes, the "Sarmatian oxen"* of the ancients, and the lineal descendant of the *urus*. Between the varieties of this breed—geographically a thousand miles apart—there is less difference than between the Shorthorn and the Longhorn of our country. Similarity of formations has produced similarity of breeds, just as differences of formations have produced differences among breeds. The converse of this, again, is true, for we find on the American continent, on the prairies, a region of land very similar to Eastern Europe, and this similarity tends to wipe out the differences between breeds. British breeds have a tendency there to lose their characteristics, and would in time, if allowed freedom, revert back to some common form when continuously bred under one set of geological surroundings. This general tendency is well known to American farmers, and is often commented on in their farm papers. The fact is recognised that it is only by the continual importation of fresh pedigree blood from this country that the special characteristics of each breed can be kept up, for if left to themselves the animals would gradually degenerate back to some of the "unimproved" ancestral forms, or else evolve some new "breed" to suit the new environment.

* "Ducunt Sarmatici barbara plaustra boves." Ovid: "A Scythian Winter."

CHAPTER XIII.

THE EVOLUTION OF LIVE STOCK.—III.

THE SHEEP.

THERE is not one of our four kinds of live stock which has been more influenced by the geological features of the country than our sheep stock—a fact which has been noticed by many observers. It has been said that if a flock of sheep were divided into lots and each lot sent to different districts of Britain and kept from interbreeding with other kinds, each would in the course of a few generations develop points and peculiarities which could easily be accentuated by selection only, and thus "breeds" be manufactured altogether different from the original strain and from each other. Notwithstanding this great influence of geological formations—or perhaps really on account of it—the author has found it very difficult to classify the various breeds into groups according to the rocks they inhabit. The modern breeds recognised by farmers and in the show-yards nowadays are no guide whatever, for the reason that the larger proportion of them have been so completely transformed by selection, crossing, and a general artificial interference with their mode of life, that a breed has often little or no resemblance to the native aboriginal variety of the district it now inhabits. Sometimes, indeed, there is no connection at all between the old variety and the new one which has completely supplanted it. An example of this is to be found in the Hampshire Down. The old Hampshire and Wiltshire sheep were horned, and of a type specifically different from that of the Down, and are now extinct if we except one or two cases where they are kept for curiosity's sake. If the modern Hampshire Down has any of the aboriginal blood in it,

it has none of the aboriginal in its appearance. Again, the Oxford Down is an absolutely artificial creation begun about seventy years ago by crossing the Cotswold, Leicester, and Hampshire Down, and then by selection and development getting it graded up to a fixed type of breed. This breed, from its descent and its habitat—the "Clays" of the South Midlands—should really not be classed as a "Down" at all, but rather as one of the "Lowland" type—in contradistinction to the other Downs which are "Upland"—though it is a "Down" in general appearance.

Sheep are essentially animals of the hills and uplands: the wastes and open spaces free from trees or thickets. In a district infested with wolves or other carnivora, these animals could not long have existed unless they kept in flocks, and as much as possible on the rocky hillsides where their power of climbing and leaping would serve in good stead if pursued. The tendency of sheep as well as of our other classes of live stock to go together in crowds—especially when alarmed—is the modern survival of a habit or instinct acquired in the wild state by their progenitors in prehistoric ages, and now turned to use for purposes of domestication, just as, conversely, the hunting instinct of the wild dog has been converted into the working instinct of the sheep-dog.

The instinctive desire of sheep for the hills and uplands, even among those breeds which have for generations been bred in the valleys or lowlands, is shown in the case of the lambs. In their play the young ones will seek any elevation, however slight, and have a game of "king of the castle"—the biggest one keeping the top. In a bare open field probably the only elevation will be an ant-hill, a tree-root, or a hedge-bank, but they will make for this as being the nearest approach to the hills and rocks where their ancestors were evolved in Pleistocene times.

The instinctive habits of upland sheep are sometimes inimical to the animals themselves when transported to the low country. As a notable instance of this the following may be quoted:—"Upland sheep used to close quick fences, when removed to fen districts where the fields are enclosed by straight canals, are not used to them, and a large loss is sustained from drowning until the sheep learn the meaning of those dark waters."*

* Parker: "Mammalian Descent," p. 65.

One other instinctive habit of sheep, however, corroborates the belief that they are hill animals, and this is the knowledge of scraping away the snow with their feet to get at the foggage beneath. The pig would be helpless in a snowstorm; the horse and the ox can shove or nuzzle off the snow with their noses if not too deep; but the sheep alone is able to survive in a high-lying country where the snow is thick and lies long.

Sheep and goats are very nearly allied, and in early times would approximate still nearer to one another. The principal difference between them now is that goats are hairy and sheep woolly, but in former geologic ages the wool of the latter would be largely replaced by hair, and the development of the wool be gradual as time went on. That the substitution of wool for hair is not yet complete is shown by the fact that flockmasters have to exercise a rigid examination in selecting rams for breeding purposes, rejecting those showing a tendency to grow too much hair at the "edges" of the fleece. This disposition is not shown so much with the lowland breeds—these being the most widely modified from the ancient forms—but is very common among the mountain varieties—that is, among those which occupy the aboriginal habitats of the race.

There seems to be very little known about the origin of the sheep kind, or its evolution during the Tertiary Ages. The first mention of it we can find is that the genus *Ovis* is represented among the fossils of the Sivalik Hills, India, of Upper Miocene Age,* but it does not appear to be known when the species *Ovis aries* evoluted. The bones of true sheep are common in prehistoric rubbish heaps, showing that they have been used by man as food as long and as early as anything else, though whether they were domesticated or not is a moot point. The bones found in the pile-dwellings of the Continent indicate that, while the animals were horned, they were more delicate in build than the ordinary kinds now, while, judging from their remains, there does not appear to have been any local variations over the whole of Europe such as we see among breeds of the present day†; but this would be difficult to tell from the bones alone.

There are at present nearly thirty distinct breeds of sheep recognised within the British Islands, but if one looks up the old

* Dana: "Geology," p. 520.
† Dawkins: "Early Man in Britain," p. 299.

writers on live stock—such as Youatt, Martin, and Low—there will be found mention made of nearly seventy. In the olden time almost every heath, forest, hill, vale, or other section of the country with a definite set of characteristics, had its own special breed, or at least variety, quite distinguishable from those round it on every side, such variations being entirely due to the geological characters of each district. Among such a complexity of varieties it is very difficult to select types for classification, but the following generalizations will be found to give some index whereby groups of similar sheep similarly situated can be classified. The ordinary style of classification is into such divisions as long-woolled, middle-woolled, short-woolled; lowland, upland, mountain; horned, polled; and so on. A closer examination often shows that many of these characteristics are adventitious, and change naturally when the habitat of the animal is changed, or when the selective and protective care of man is withdrawn. Take the case of horns *versus* bare polls, for instance. Hornless sheep were common in the days of the Romans, but from analogy all sheep must have been horned at one time, as some of the breeds are yet,* such as the Welsh, Irish, Exmoor, and Blackfaced. If they were not horned in the days when wolves, foxes, and other carnivora were plentiful, it is difficult to see how they could defend themselves and survive at all. With horns the matter was easy, for a horned ewe to-day, when protecting her lamb, will face and beat off any dog or fox if she has an open field and no favour.

It is possible to group all, or nearly all, of the old breeds into some half-a-dozen types, the members of which have a certain amount of similarity among themselves as to their characteristics, as well as a similarity of the formations upon which they are found. These are as follows:—

1. The Leicester or Lowland type.
2. The Upland or Red Sandstone type.
3. The Horned Down or Chalk type.
4. The Sussex Down or Polled Down type.
5. The Blackface or Limestone type.
6. The Mountain or Archæan type.

The adjoining illustrations give portraits of a typical animal of each class, either ancient or modern.

* Dawkins: "Pleistocene Mammalia," p. 14.

FIG. 17.
LOWLAND (LEICESTER).

FIG. 18.
UPLAND (EXMOOR).

FIG. 19.
HORNED DOWN (OLD WILTS).

FIG. 20.
SUSSEX DOWN.

FIG. 21.
LIMESTONE (BLACKFACE).

FIG. 22.
MOUNTAIN (OLD WELSH).

1. Leicester or Lowland Type.—In this group we include the following old breeds :—

Teeswater.	Sherwood Forest.	Bampton Nott.
Mugg.	Charnwood Forest.	Kent.
Wensleydale.	Cotswold.	Roscommon.
Lincoln.	Evesham.	(Cheviot.)
Leicester.	Devon Nott.	

All these animals were long-woolled, all were polled, all were large, heavy sheep, and all were confined to the alluvial soils or valley bottoms—principally, or almost wholly, on the Trias and Oolite in England (the Great Central Plain of the country), and in the case of the Roscommon, on the Western Central Plain of Ireland. The Cotswold is an apparent exception, but the Cotswolds are not hills "to one who has roamed o'er the mountains afar," but only tablelands of the moderate elevation of under 1,100 feet ; while the old sheep of the adjoining Vale of Evesham were very similar and of the same type with slight variations due to the lithological nature of their footing.*

The case of the Cheviot calls for some remarks. In working out these geological classifications we have had some difficulty in knowing where to place this important breed, on account of the fact that originally it was more of a mountain than a lowland variety, flourishing in the hill regions where the Leicesters would not thrive,† and it almost deserves a class to itself like the Sussex Down. Low points out the peculiarity that it is derived from a district of "porphyry,"‡ in apposition to its neighbour the Blackface on the "grauwacke," and Wrightson says :—"The fact of a well-defined breed occupying a limited area such as Cheviot, and bearing no special resemblance to any other breed of sheep, is a curious fact, and one upon which little light can be thrown."§ Regarding the modern Cheviot, however, we have no hesitation in putting it in the Leicester or Lowland type. In 1756, Lincoln tups were introduced to cross with the aboriginal Cheviot || ; later on, Martin says, it was crossed with the Leicester ¶ ; Youatt quotes a statement that repeated crossings

* Youatt : "Sheep, &c.," p. 261.

† Darwin : "Animals and Plants under Domestication," Vol. I., p. 100.

‡ "Domesticated Animals," pp. 85 and 93.

§ "Sheep : Breeds and Management," p. 88.

|| Ibid., p. 89.

¶ Martin : "Sheep, &c.," p. 10.

with the Leicester gave the breed its white face and legs*; so that, apart from the modern practice of crossing with Wensleydale Leicesters to produce the "half-breeds" or "white-faces" so much in demand for turnip feeding by the farmers in Scotland, it is distinctly of the Leicester type.

Again, it is a Lowland sheep in comparison with the Blackface which occupies the Highlands and all the hill country of Scotland, while from a geological point of view it is most remarkable how this breed follows the lowlands on the Old Red Sandstone, from the Cheviot felsite and trap district right up the east coast of Scotland to Caithness, and how it avoids the "grauwacke" where the Blackface reigns supreme. Indeed, if the rocks of Cheviot Fell are of Old Red Sandstone age, then the Cheviot might be called the Old Red Sandstone breed, and the aboriginal form put into the next class.

2. Upland or Red Sandstone Type.—Stretching from Cornwall to Cheshire there is a range of country in which Red Sandstone in its various forms of Devonian, New Red, and Triassic predominates, and among some eighteen old distinct breeds inhabitating this stretch of country there was a remarkable amount of similarity. These were :—

Cornish.	Dean Forest.	Morfe Common.
Dartmoor.	Monmouth.	Teddesley.
Exmoor.	Brecknocks.	Cannock Chase.
Porlock.	Clun Forest.	Tadpoles (Shawberry).
Somerset.	Malverns.	West Staffords.
Mendip.	Ryeland.	Delamere Forest.
Vale of Glamorgan.		

The similarity among these breeds consisted in the following points :—They were small sheep; they preferred the uplands or higher parts in contradistinction to the sheep of the Leicester type, which preferred the valley bottoms and alluvial tracts even where these overlaid Red Sandstone formations; they were short-woolled; they were horned, but the horns were comparatively small; and they had mottled or coloured faces and legs, where most of the neighbouring types were white. Some of the present day descendants of these are, of course, hornless, as the Ryeland, while in others the rams only are horned, but horns would be universal at one time in their history.

* Youatt: "Sheep, &c.," p. 113.

3. The Horned Down or Chalk Type.—A remarkable group of sheep were to be found stretching in a line along the Chalk escarpment from Dorset to Norfolk, the members of which—judging from the old prints—resembled one another very much. The principal varieties of this family were :—

Portland.	Hampshire.	Berkshire.
Dorset.	West Down.	Norfolk.
Wiltshire.	Banstead Down.	

The predominating characteristics of these breeds were that they were all fairly large, upstanding, clean-legged animals, had large *spiral* horns, were short-woolled, had white faces and legs, and were indigenous to the cretaceous tract of country stretching diagonally across the south-east of England from the Bill of Portland to the Wash. All of them are extinct excepting the Dorset,* which was the ancestor of the modern Somerset and Dorset pink-nosed horned sheep. The Hampshire Down and the Suffolk Down now occupy the region of the others, and though probably some of the old blood was retained in these modern breeds when they were originally made by the breeders of long ago who introduced the Down type, yet the Down varieties of to-day are absolutely different kinds of animals, with nothing in common with their predecessors excepting the soil of the uplands they feed on. A good illustration of the difference between types of sheep is quoted by Darwin from Marshall.† Lincoln sheep and Norfolks were mixed in one flock, but the Lincolns gradually drew off to the low-lying heavy soil, while the Norfolks sought the higher, lighter, and drier land.

4. The Sussex Down or Polled Down Type.—In discussing the old breeds of this Down type, we discover the remarkable fact that the only representative of this class is the South Down itself—the small, polled, short-woolled, brown-faced animal of the chalk hills of Sussex.

In our days we are accustomed to see some five Down breeds occupying the whole south-eastern quarter of England, but four of these are modern creations due to the interference of man, and, as

* A Norfolk Horn won first prize in the carcase class at the recent (1900) Smithfield Show, and there is reported to be a flock of Wiltshire Horns still in existence in North Wales.

† "Animals and Plants under Domestication," Vol. I, p 100.

shown above, have no similarity or connection with the native breeds which developed in their respective districts when the natural environment was allowed full sway.

We must confess that the existence of the Sussex Down in the olden times is a puzzle. It was there when Cæsar landed his Roman veterans at Pegwell Bay, and if there were not a flock of them then at Ebsfleet Farm to which the Legions helped themselves, there would be plenty not far away. Contrast this with the fact that after the Battle of Hastings, in 1066, the slain were eaten by wolves which infested the Downs and the Weald in those days. How a small hornless breed contrived to exist in a district where wolves were plentiful is the puzzle, though perhaps it is no greater puzzle than in the case of some of the small heath breeds, even where they had horns.

5. The Blackface or Limestone Type.—In the Pennine Range we find a very large development of the Mountain Limestone, and along these hills we also find a group of sheep, most of which nowadays are recognised as distinct breeds, but which have a large amount of resemblance between themselves, and differ very greatly from the neighbouring varieties of Leicester or other types. These are :—

Limestone.	Silverdale.	Lonk.
Penistone.	Woodland.	Blackfaced.
York Moorland.		

Some will, no doubt, be surprised to see the Blackfaced included in a Limestone group, seeing that it is the sheep which in Scotland occupies all the hill and mountain country where nothing but Silurian, Cambrian, and Laurentian slates and schists are to be found ; but a study of types of known history, and of present day facts, is convincing that this variety originated on the Mountain Limestone, just as did their near relatives the Lonks, and that it is on the limestone tracts of Central Scotland where it is now to be met with in its best developed form. King James IV. is said to have introduced it into the Forest of Ettrick, from whence it has spread over all the Highlands of Scotland to the exclusion of the aboriginal mountain breeds. If this is so, he did not go far across the Border for the imported stock ; and the spread of the breed into Silurian and other old regions is comparatively recent. The author's grandfather informed him that in his youth, in the

times of Bonaparte and Waterloo there were very few in Galloway, but that the common sheep had the dun face and bluish-coloured wool of the aboriginal breed of Scotland, and this old breed lingered on in corners well into the nineteenth century. Flockmasters of the Highlands and other Blackface districts know well the amount of care which requires to be taken in selecting the breeding ewes, in rejecting those with too much hair among the wool and with faces and legs badly coloured, and in purchasing good rams to keep their flocks up to the mark. If all this care were given up, and the sheep allowed to breed as they like, they would revert in a few generations to a very inferior type—approximating to the old-fashioned tribes which preceded them.

6. Mountain or Archæan Type:—

Shetland.
St. Kilda.
Galloway.
Scottish Dunfaced.
(Herdwick).
Isle of Man.
Anglesea.
Radnor Tanface.
Llongmynd.
Welsh Soft-woolled.
Welsh Mountain.
Glamorgan Mountain.
Scilly Islands.
Wicklow (Cottagh).
Kerry.

It will be noticed that the habitats of all these breeds are on the older and harder rocks—that is, the more rugged parts of the country where there is a predominance of bare rock belonging to the formations from the Silurian downwards, and where there is generally a lesser amount of surface accumulations of transported material. This group probably includes the most aboriginal forms—if we may coin a term—because they are to be found to the west and north, like the *Bos longifrons* among cattle, in districts where there were greater opportunities for them to run wild and less chance of mankind artificially selecting, crossing, &c., until within the last generation or two.

There is, of course, a considerable difference between some of the breeds as between north *versus* south, or hill *versus* dale, but on the other hand the resemblance among them is greater than that between the adjoining types of, say, the Leicester or the Blackface groups.

They were all horned excepting in the case of the Wicklow, and perhaps some of the others—such as the Welsh Soft-woolled—where

the horns were "going out"; the horns were not so large or spiral as with the Blackface or the Horned Downs, being more of one regular curve after the goat type—the old Scottish Dunfaced especially being goat-horned and short-tailed (*Ovis aries: brachyura*)*; the wool was short and of very fine quality, notably so in the case of the famous Shetland and Welsh wools, but almost equally so with many of the others; while the animals were generally small and proportionally long in the legs to enable them to roam over the scanty pastures of steep hillsides.

Not more than half of the breeds of this group are now existent, and these in many cases have been greatly modified by selection, but seldom by introducing fresh blood. It is a remarkable fact that attempts to improve some of the varieties by the introduction of Blackface, Leicester, or Down rams have not been successful, and improvement has come chiefly or wholly by selection among the individuals themselves of a given breed. This, of course, is due to the fact that they are largely the native animals of the high-lying and mountainous regions of the old indurated formations, and that any of the other breeds—excepting perhaps the Blackface—are more tender and less hardy than these.

The Herdwick is exceptional, and calls for some special remark. It is said that the breed is descended from forty sheep which were cast ashore at Drigg, on the coast of Cumberland, from the wreck of one of the ships of the Spanish Armada. If this is correct—and no doubt it is—then this breed is not, of course, aboriginal in the same sense as the others, though now developed for three centuries on the Primary formations. If the original forty sheep came from Spain, then there is a likelihood that they were of the same strain as the Merinos, and it would be interesting to know if there is any resemblance between the two breeds now in addition to the head and spiral horn. The hairiness of some of the fleeces agrees with the characters of the Merino, for hairy lambs and sheep are common in this latter breed, even after eleven centuries of breeding.†

Before passing from this subject we must call attention to a generalized geological classification of sheep, first propounded in 1870 by Brown, then a land agent in the North of Scotland,‡ but

* Munro: "Scottish Lake Dwellings," p. 140.
† Bond: "Origin of the Merino Sheep," p. 17.
‡ Brown: "British Sheep Farming."

which is here greatly modified and elaborated in the accompanying diagram. (Fig. 23.)

Dividing all breeds of sheep into five leading types—Leicester, Uplanders, Downs, Blackfaced, and Mountain—it is shown how the Leicesters kept to the lowest grounds on the Alluvium and Sandstone formations; the Uplanders are found most

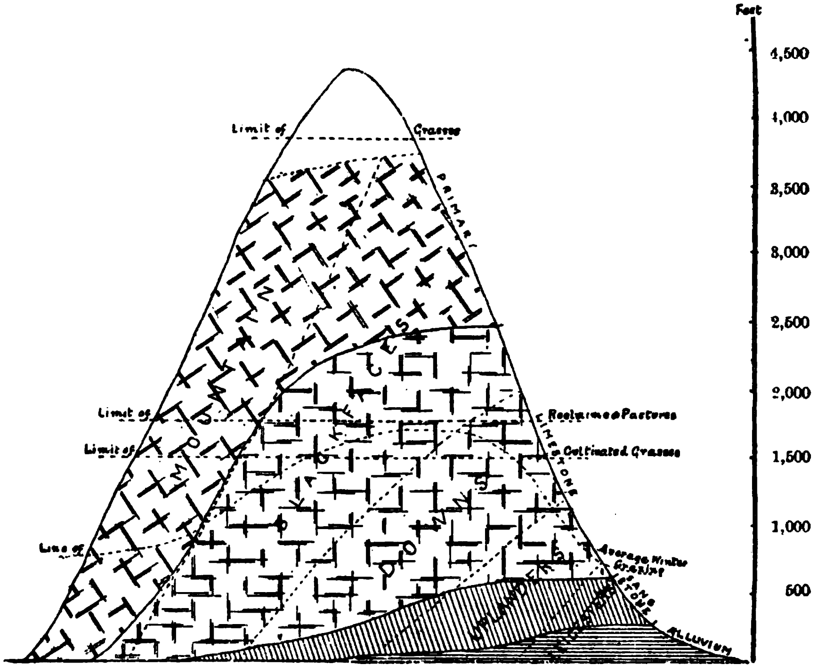


Fig. 23.

Characteristics of British Breeds of Sheep.

largely on the Sandstone; the Downs go higher on the Limestone (Chalk) rocks; the Blackfaces higher still, partly on the Limestone and partly on the "Primary" (including in this latter the older indurated) rocks; and the Mountain breed are almost wholly confined to the "older" formations and at the highest range. Further, it is shown that the "line of average winter grazing" is very low on the Primary and Sandstone divisions (about 700 feet above sea-level) while on the Limestone (including

the Chalk) it rises to about 1,700 to 1,800 feet. Latitude has, of course, much to do with this—that is, the Limestone and Chalk in England have a better climate owing to being in the south than do the Schists of the Highlands lying in the north—but the lithological character of the prevailing rocks has much more to do with it ; a statement proved by the fact that the range of wintering with the Leicesters on the Sandstone rocks is only up to some 700 feet above sea-level – that is, about the same as the Blackfaces on the northern "Primary" rocks. Brown's little book first suggested to the author the influence which geological formations have on the live stock which have been developed on their outcrops, and which, after twenty years of study and research, he is now elaborating on the methods described in these notes.

The character of the wool of a sheep is largely influenced by the nature of the ground over which the animal ranges. The deleterious effect of the chalk or lime of a limestone formation has long been known, and as long ago as 1837 Youatt suggested an explanation of this.* Minute particles of chalk or limestone become entangled in the wool and have a corrosive effect on the fibre and harden it, and render it less pliable ; the action being, in fact, similar to separating the wool from the pelt by the action of lime-water in the work of the fellmonger. Youatt also suggested that another action was taking place, though little suspected. The "yolk" of the wool is a fatty excretion of complex composition, amounting to some 15 per cent. of the total weight of an unwashed fleece in average cases : when limey matter comes into contact with this there is a chemical union, and a true soap is formed which tends to wash out with the rain, thus depriving the wool of its "natural pabulum and unguent," and causing a certain amount of harshness in the same. Youatt quotes a case given by the great Bakewell of a district in the north of Derbyshire, where a "fault" separates the limestone from some siliceous grit formations.† The wool off the sandstone was worth in the market in his day 1s. to 1s. 6d. per tod more—say one halfpenny per pound—than that off the limestone, though it was the same breed of sheep in both cases, and the flocks were similarly treated by the farmers. Conversely, of course, the sheep themselves would thrive best on the limestone—would be healthier and yield better mutton—but the

* "Sheep, &c.," p. 76.

† Probably the Mountain Limestone and the Millstone Grit. *R. A. S. E Journal*, 1875, p. 321.

fact remains that all limestone formations tend to make the wool of the sheep thereon "harsh" and unpliable. Even the pure limpid water off limestone rocks must not be used for fleece washing for the same reason. On the other hand the wool of sheep grown on valley bottoms and alluvial soils is soft and silky, and long, of which the Leicester and Lincolns are examples. This variation in the quality of wool depending on the nature of the soil is commented on by Rogers in his "Six Centuries of Work and Wages" (abridged edition, p. 82), in the following words:—"Goodness of wool in England is not so much a matter of breed as of soil, and I am told that the localities which supplied the best English produce in the fifteenth century and in the centuries before that period are characterized by analogous excellence in the nineteenth."

The character and quality of wool is, indeed, so much a matter of locality—that is, of soil and rock formation—that the value of the "clip" of individual farms is well known to the wool brokers, and at some of the Highland markets, for instance, the wool is sold by "character"—that is, the merchant buys it without seeing even a sample of it, as he knows from former experience the nature of the produce of each farm. Bakewell classed wool soils thus: Clay, the best: sand next; lastly, lime, or of that nature.

Another point in which the wool is directly influenced by the soil is in the matter of colour. Wool, when washed and dressed, ought, of course, to be white, or nearly so; but in the unwashed state on the back of the sheep it is full of dirt—that is, particles of the soil on which the animal is grazing and lying down. On the red soils the wool takes a reddish or brown tint, on slaty hills it is bluish, and so on; and if sheep from different soils, or even from adjacent farms, are mixed it is often quite possible to distinguish the members of each lot by the colour alone, until they have been long enough on the same land together to get all the same tint. This tendency is probably at the bottom of the custom of artificially colouring the wool with various varieties of ochre or ruddle for show-yard purposes. The sheep are all thus made uniform in appearance, though undoubtedly the custom is nasty where carried to extremes.

The effect of clay formations—as the Oxford Clay—in developing such diseases as liver-fluke and foot-rot, and the healthiness of limestone soils, have already been commented on, but all go to show how much the sheep is influenced by the land it feeds over.

CHAPTER XIV.

THE EVOLUTION OF LIVE STOCK.—IV.

THE PIG.

AFTER a study of the skulls of all sorts of swine, Rolleston came to the conclusion that the prehistoric British Pig is descended from the *Sus scrofa* variety *ferus*,* though the transportability and diffusibility of the animal makes it possible that it was of Asiatic or African origin as far back as the Stone Age. Rütimeyer, on the other hand, held that the Berkshire breed was descended from the *Sus celebensis*, but this can hardly be so, or else there are a great many other breeds from the same source, as the Essex and the Dorset, which are not specifically distinct from the Berkshire as are the Tamworth and the Yorkshire. Two varieties—the Turf Hog (*Sus palustris*) and the Domestic Hog (*Sus scrofa domesticus*)—have been formed in the pile dwellings of the Continent, and some hold that our present pig is a hybrid between these.†

Darwin has summed up the evidence of various observers regarding the genealogy of the domestic pig, from which it appears that there were two distinct strains. The one is the Wild Boar (*Sus scrofa*)—found throughout the temperate and hot regions of Europe, Asia, and North Africa—and the other the Chinese Pig (*Sus indicus*), small, short-legged, and short-headed‡—introduced into Britain after trade with China became developed. The breeds of the British Islands have, therefore, been derived from these two, mostly by intercrossing; while, by selection, the result—though more valuable than either of the original forms—has developed under the care of man so as to have little in common with those forms as far as appearance goes in many cases.

---

* Rolleston: "The Domestic Pig of Prehistoric Times." *British Association*, June, 1876.

† Dawkins: "Early Man in Britain," p. 95.

‡ Dawkins: "Pleistocene Mammalia." *Palæog. Soc.*, 1878, p. 13.

It is customary for books on pigs to mention the influence which the Neapolitan pig has had in modifying our home breeds,* but we are unable to find any scientific writer who takes notice of this, or shows that the Mediterranean variety differs specifically from the *Sus scrofa.*

The first recognisable ancestor of all our swine was the previously mentioned *Hyracotherium*, followed by the *Pliolophus*, found in the London Clay of the Lower Eocene.† These were succeeded by such forms as the *Dichobune* of the Upper Eocene, the *Chœropotamus* of the Upper Oligocene, the *Hyotherium* of the Lower Miocene, and finally *Sus* (including all varieties and species) in the Upper Miocene and Pliocene, as set forth by the investigations of M. Gaudry.‡ The hippopotamus, tapir, and some other animals seem to have had a closely allied descent; but in the earlier stages of the Eocene the various kinds of animals in existence were not specially differentiated into ruminating, graminivorous, omnivorous, &c., the *Dichobune*, for instance, being a ruminant—a small animal related to both the pachyderms and antelopes—so that, as early as this the omnivorous character of the pig was beginning to show. The earliest occurrence of the true hog in Britain appears to be in the Post-Pliocene Forest Beds of Norfolk.§

Very little is known about these ancestors of the pig, either fossil or prehistoric. In the early ages there appears to have been only the one variety, common all over western Europe, and represented by the wild boar of historic times and of the present day. This animal was of a dusky brown or even slaty colour, with bristles of a lighter or silvery shade, and was represented more nearly in recent times among the domesticated or semi-domesticated breeds of the Highlands and Islands of Scotland,|| Isle of Man, Cheshire, Tamworth, Old Berkshire, and Channel Islands.

At what period the aboriginal swine began to differentiate into the various breeds now or recently known it would be difficult to say, though we believe for historic reasons it must have been in Saxon times. Swine herding was an important avocation in the days when the land was more or less one continuous huge forest,

* Low: "Domesticated Animals," p. 433.
† Wallace: "Distribution of Animals," p. 216.
‡ Prestwich: "Geology," Vol. II., p. 437.
§ Heilprin: "Distribution of Animals," p. 374.
|| Wilson: "British Farming," p. 503.

and oak and beech most plentiful. Sounders* were looked after and kept in one district—that is, in one environment—more carefully than some of the other breeds of live stock, and thus there was more chance given for the evolution of local varieties. The introduction of the *Sus indicus*, in the shape of the Chinese crosses, altered the character of many of these varieties, and in one sense completely obliterated the feral colouring, but still there are some points regarding the same which are interesting and instructive.

The change between the aboriginal wild boar and his modern descendants is well illustrated in the annexed boars' heads: the Berkshire boar has lost the huge tusks and the coarse, bristly hair, and acquired the smooth, fat outline which indicates the production of best mild-cured breakfast bacon. (Figs. 24 and 25.)

FIG. 24.

WILD BOAR.

FIG. 25.

BERKSHIRE BOAR.

All our modern and ancient breeds of pigs—going back, say, 200 years—naturally divide themselves into three classes according to colour—the white, the black, and the brown; and in each group we find old breeds or distinct varieties given by the old writers as follows:—

White—

Yorkshire.	Salford.	Norfolks.
Cumberland.	Northampton Whites.	Suffolk White.
Lancashire.	Lincoln (Fens).	Welsh.
Coleshill.		Irish "Greyhound."

* A "sounder" is a herd of wild swine.

Black—

Berkshire.	Rudgwick.	New Forest.
Leicester.	Tunbacks.	Oxford.
Suffolk.	Maylams.	Dorset.
Essex.	Hampshires.	Devon.
Sussex.	Wiltshires.	

Brown—

Tamworth.	Leicester.	Warwick.
Cheshire.	Worcester.	

Now the remarkable fact about these three classes is that each keeps to its own region, as far as the original habitat is concerned, even in the present day. The blacks are to be found in one continuous area in the south-east of England, the whites in the north and north-east, and the browns in the middle. To our mind it is not merely an accident that the whites are found on the older formations—on the Mountain Limestone in particular (like the Shorthorns) downwards—the blacks on the newer beds from the Oolitic upwards, while the *reddish* breeds stick to the *red* soils of the Midlands on the Permian and Triassic. There is a certain amount of similarity between sheep and swine in this respect. The black pigs and the Down breeds (ancient and modern) occupy the same area, the brown pigs and the sheep of the Leicester type of the Midlands go together, while the white pigs and the northern sheep of the "Backbone of England" have the same habitat to a large extent. Still another point of resemblance is that of the black group of pigs which occupies the same area as the Down breeds (old and new), which sheep have the blackest hair on their faces and legs in the case of at least four of these kinds, the Suffolk sheep, for instance, being the "veriest niggers of the sheep kind." This, we believe, is not an accidental occurrence, though we cannot give a reason for it.

Only some six breeds are recognised nowadays by the National Pig Breeders' Association, but the same rules and conditions apply to these as stated above in connection with these ancient varieties. Of course, in modern times, when railways promote interchange of stock, one may meet with individual herds of one kind in the middle of the habitat of another kind, while in Scotland—which had no specific breed excepting the one general wild one—any and every variety of black or white has been made to develop pork if not to pay the owners; but the fact remains that there has been

the general conformity of groups of breeds to groups of formations both in the past and present, while from analogy we infer that the great variety of formations is at the bottom of the great variety of breeds, though we cannot at the present stage of this inquiry go any closer into details, but must simply confine the question to generalities.

The principal change which has taken place in the conformation of the pig, apart from the evolution of breeds, is in the matter of fatness,* since prehistoric (as opposed to geologic) times began. Aboriginal wild pigs were razor-backed, slab-sided, and wedge-snouted, and able to run like the wind, but their modern descendants are just able to waddle from their beds to their troughs and back again, while in shape they are like huge sausages on legs. Coming to details, the modern pig, as compared with his immediate fossil ancestor, has a much shorter snout (turned up in some cases); the canine teeth are very much reduced, so that they scarcely deserve the name of "tusks"†; the bones have become much smaller generally, and have fewer "processes" about them—as, for instance, the "acromion process" of the scapula is small in the domestic pig, but is an immensely enlarged and doubled-over piece of bone in the Westphalian wild boar; the legs are shorter, and while nominally there are two functional digits on each foot, the enormous weight of the domestic animal is relatively so great that the phalanges have yielded in the older animals so much as to let down the other two digits (2 and 5) so far that they actually become functional, and there may thus be four usable hoofs on each foot.

Thus far the author has got in his inquiries, but it seems to him that he has only made a beginning to the subject, and that the directions in which further research is desirable and necessary are numberless. It is humbly suggested that great scientists might turn their energies in some of these directions so as to make their studies of some use. The spectacle has been seen of an eminent botanist wasting his time and abilities over an insignificant weed like the "shepherd's purse," and neglecting the much more important food-plants; a great anatomist engrossed in the study of the bones of the frog, and passing by the domestic animals; and a

* Dawkins: "Pleistocene Mammalia." *Palæog. Soc.*, 1878, p. 36.
† Dawkins: "Early Man in Britain," 1887.

great geologist investigating the composition of the unimportant mineral known as "camptonite," while the mineralogy of the soil was reckoned of no account. If these and many others in like positions would take up matters of use to the human race, we might progress in farming and many other branches a good deal faster.

Within the last few years the study of Nature has advanced among educated people, and the introduction of the teaching of "Nature knowledge" into schools is certain to be followed by the most beneficial results among the mass of the people, as it will teach them to love the country for its own sake, and to prefer to live there instead of crowding into towns: and in helping to develop one branch of natural science the author is following the bent of his own mind in giving it a practical turn. Himself a countryman, and one of the hill-folk, he has long studied the country, and has endeavoured in these pages to put down some of the things there are to be seen and known from a geological point of view when a farmer looks across the landscape, takes up a handful of soil for examination, selects the crops most suitable for his farm, or endeavours to improve his live stock.

The country has a never-ending charm for many; there is a great wide sky above, reaching from hill to hill and all round the horizon; there is a many-patterned carpet over the surface of the earth, and many interesting things to be dug out of that earth; there are wet days and dry days; there is summer and winter; there are, in short, many things amid a continual change of scene.

"The oaks of the mountains fall;
The mountains themselves decay with years;
The ocean shrinks and grows again;
The moon itself is lost in heaven."

FINIS.

APPENDIX.

TABLE OF THE BRITISH STRATA.

Period.	Epoch.	Series.	Formation.
Contemporary or Recent.	...	...	Blown Sand. Shingle. Peat Moss. Warp. Alluvium.
Quaternary or Post-Tertiary.	Pleistocene ...	Post-glacial	Brick Earth : Loess. Terraces. Estuarine Deposits. Raised Beaches.
		Glacial ...	Kames or Eskers. Moraines. Boulders and Erratics. Post-glacial Sands and Gravels. Upper Boulder Clay. Interglacial Sands and Gravels. Lower Boulder Clay.
Tertiary or Kainozoic.	Pliocene... ...	...	Norwich Crag. Red Crag.
	Miocene... ...	...	Lenham Sands.
	Oligocene ...	Upper... ...	Hempstead Beds — Fluvio-Marine Series.
		Middle ...	Bembridge Beds — Fluvio-Marine Series.
		Lower... ...	Osborne and Headon Beds — Fluvio-Marine Series.
	Eocene	Upper... ...	Upper Bagshot Beds. Barton Clay. Bracklesham Sands. Lower Bagshot Sands.
		Lower... ..	London Clay. Oldhaven Beds. Woolwich and Reading Beds. Thanet Sands.

Period.	Epoch.	Series.	Formation.
Secondary or Mesozoic.	Cretaceous ...	Upper... ...	Upper Chalk with Flints.
			Lower Chalk without Flints.
			Chalk Marl.
			Upper Greensand.
			Gault.
		Lower or Neocomian	Lower Greensand.
			Folkestone Beds.
			Kentish Rag.
			Atherfield Clay.
			Weald Clay.
			Horsham Stone.
			Hastings Sands.
	Jurassic	Upper Oolites	Purbeck Beds.
			Portland Stone.
			Kimmeridge Clay.
		Middle Oolites	Coral Rag.
			Calcareous Grit.
			Oxford Clay.
			Kelloway Rock.
		Lower Oolites	Corn Brash.
			Forest Marble.
			Bradford Clay.
			Great Oolite.
			Stonesfield Flags.
			Fuller's Earth.
			Inferior Oolite.
		Lias	Midford Sands.
			Upper Lias Clay.
			Marlstone.
			Lower Lias Clay.
	Triassic	Upper... ...	Rhætic or Penarth Beds.
		Middle ...	Keuper Marl.
		Lower... ...	Waterstones.
			Bunter Sandstones.

Period.	Epoch.	Series.	Formation.
Primary or Palæozoic.	Permian...	Upper...	Magnesian Limestone.
		Lower...	Lower Red Sandstone.
	Carboniferous	Upper...	Coal Measures.
			Millstone Grit.
			Yoredale Rocks.
		Lower...	Mountain Limestone.
			Carboniferous Shales.
	Devonian (Old Red Sandstone)	Upper...	Old Red Marl.
		Middle	Cornstones.
		Lower...	Old Red Conglomerate.
			Tilestones.
	Silurian ...	Upper...	Ludlow Beds.
			Wenlock Beds.
			Woolhope Limestone.
			Coniston Limestone.
		Lower ...	Bala and Caradoc Beds.
			Llandeilo Beds.
	Cambrian	Upper...	Tremadoc Slates.
			Lingula Flags.
		Lower...	Menevian Beds.
			Longmynd and Harlech Beds.
	Archæan ...	...	Pre-Cambrian.
			Huronian.
			Laurentian.
Crystalline and Igneous.	Grauwacke.		
	Volcanic Agglomerate.		
	Felspathic Group.		
	Porphyry.		
	Felstone or Felsite.		
	Basalt.		
	Diorite.		
	Hornblende Rock and Schist.		
	Diabase and Diallage.		
	Serpentine.		
	Mica-Schist.		
	Syenite.		
	Granite.		

INDEX.

CONTENTS.

SPECIMEN PAGE.

LABOUR.

PLOUGHING.—*Quantity ploughed:*—¾ to 1 acre daily—8 hours.

Extent of Land Ploughed by Fowler's Double-Engine System:—2 acres per 10 hours for each furrow—8 acres in all.

DIGGING.—To dig with a spade an acre of land from 9 to 12 inches deep, a man will take from 14 to 21 days in recently moved soil. If old lea, will take, in some cases, double this time.

Steam Digger:—5 acres per day, 8 to 10 inches deep.

CULTIVATING.—Does not bring up raw soil or bury fine top mould, and does not promote evaporation; mixes and pulverises the soil, and is the best kind of cultivation. 3 horses with 13-tine spring-tooth grubber, on light land, can cultivate 1 acre per hour, 3 to 5 in. deep; 4 horses on heavy land.

Ground Cultivated with Steam Grubber:—Double-engine system, 10 acres; single-engine system, 6 acres. Both 8 in. deep—10 hours.

SOWING.—*Quantity of Land Drilled per Day:*—1·25 acres per hour, employing 2 to 3 horses and 2 to 3 men. Steam, 20 acres.

Quantity Sown with Hand:—1½ acres per hour, single-handed.

HARROWING.—*Quantity done per Day:*—Zig-zag 7-ft. harrow will give 1·25 acres per hour a single stroke. Steam, 30 acres.

ROLLING.—*Quantity done per Day:*—8 to 10 acres.

FALLOW-CROP DRILLING.—*Quantity Drilled per Day:*—3½ to 5 acres with double-mouldboard plough and drills at 27 in.

POTATO-PLANTING.—*Number of People required:*—2 men and 4 horses to open and close drills; 5 or 6 women to spread manure; 6 or 7 women planting sets; 1 man sowing artificial manures; 4 men and 4 horses carting manure to drills from dungstead, if near at hand; 2 men filling carts at dungstead. Men or boys replace women in the South. 0·4 acre finished per hour.

Cutting Sets:—A woman should cut about 8 to 10 cwt. of potatoes per day, with early kinds of seed; late varieties will be less.

SETTING PLANTS.—From 15,000 to 20,000 can be dibbled in one day by two men, with boys to carry and help.

SOWING TURNIPS OR OTHER DRILLED CROPS.—With a double-drill machine and 27-in. drills, 1 acre per hour nearly can be done.

NOTE-BOOK

OF

Agricultural Facts and Figures.

EXTRACT FROM THE PREFACE.

This Note-Book makes no pretence to originality, either in the style or matter. When an agricultural student under Professor Wilson at Edinburgh, the author oftentimes felt the great want of a book containing all the data connected with the subject he was studying. The various facts which even those with the best of memories are continually forgetting, are scattered through numberless books and papers, necessitating in some cases a troublesome search, especially annoying to anyone preparing for an examination. The great value of Molesworth's "Pocket-book of Engineering Formulæ" to engineers, and of similar books to those engaged in other professions, was so apparent to the author, that it occurred to him that a book compiled in the same style, and devoted to farming matters, could not fail to be useful as a ready means of reference for refreshing the memory.

With this end in view the collecting of notes from all the standard text-books on agriculture within reach was commenced and carried on for several years, and the result, arranged as methodically as possible, is now given to the public. Besides these, a large number of journals, papers, lectures, &c., have been consulted, and the whole has been supplemented and modified from the author's own practical knowledge gained on the farm and elsewhere.

EXTRACT FROM PREFACE TO THE SIXTH EDITION.

The "Note-Book" has met with so much success that I am encouraged to make it as full as possible, while taking the greatest pains to have the information reliable in the minutest detail. Nearly the whole has been re-written, as the amount of matter contained in this edition is three times that of the first one.

The "Note-Book" form has been abandoned for convenience.

OPINIONS OF THE PRESS.

"No farmer, and certainly no agricultural student, ought to be without this *multum in parvo* manual of all subjects connected with the farm."—*North British Agriculturist.*

"This little pocket-book contains a large amount of useful information upón all kinds of agricultural subjects. Something of the kind has long been wanted."—*The Mark Lane Express.*

"The amount of information it contains is most surprising; the arrangement of the matter is so methodical—although so compressed—as to be intelligible to every one who takes a glance through its pages. They teem with information."—*The Farm and Home.*